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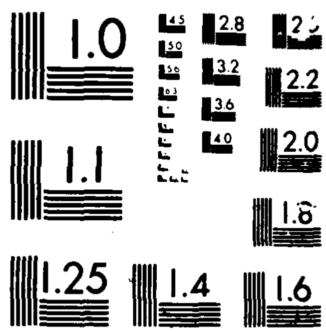
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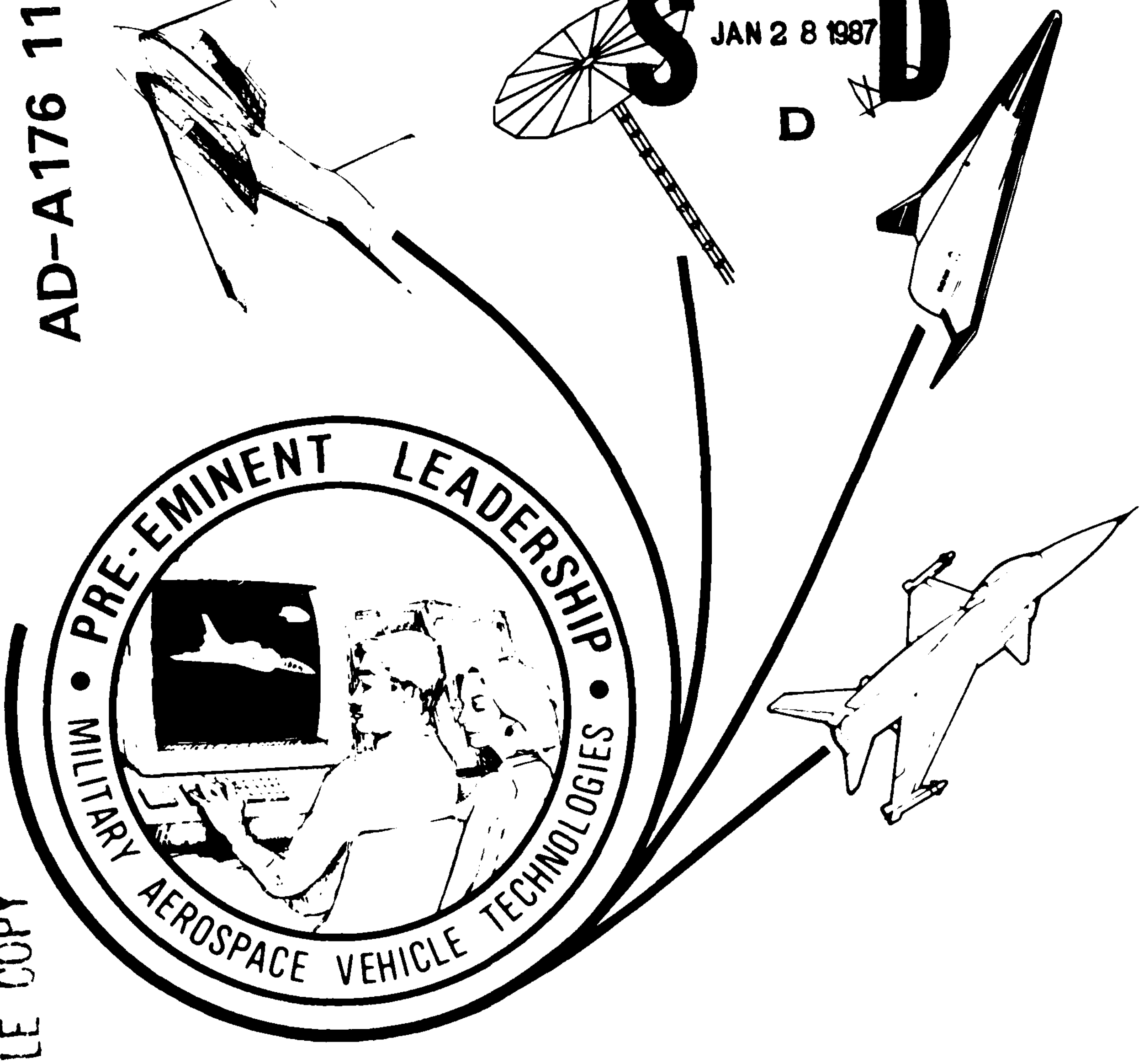
AIR FORCE TECHNICAL OBJECTIVE DOCUMENT

FLIGHT DYNAMICS LABORATORY PLANS

JULY 1986 FOR FISCAL YEAR 1988



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This document has been reviewed and is approved for publication.

THADDEUS H. SANDFORD
Colonel, USAF
Director, Flight Dynamics Laboratory

FOREWORD

The Air Force Technical Objective Document (TOD) programs is an integral part of the process by which the Air Force plans and formulates a detailed technology program to support the development and acquisition of Air Force weapon systems. Each Air Force Laboratory annually prepares a Research and Technology (R&T) Plan in response to available guidance based on USAF requirements, the identification of scientific and technological opportunities, and the needs of present and projected systems. These plans include proposed efforts to achieve desired capabilities, to resolve known technical problems and to capitalize on new technical opportunities. The proposed efforts undergo a lengthy program formulation and review process. Generally, the criteria applied during the formulation and review are responsive to stated objectives and known requirements, scientific content and merit, program balance, developmental and life cycle costs, and consideration of payoff versus risk.

It is fully recognized that the development and accomplishment of the Air Force technical program is a product of the teamwork on the part of the Air Force laboratories and the industrial and academic research and development community. The TOD program is designed to provide to industry and the academic community, necessary information on the Air Force laboratories' planned technology programs.

Specific objectives are:

a. To provide planning information for independent research and development programs.

b. To improve the quality of the unsolicited proposals and R&D procurements.

c. To encourage face-to-face discussions between non-government scientists and engineers and their Air Force counterparts.

One or more TODs have been prepared by each Air Force laboratory that has responsibility for a portion of the Air Force Technical Programs. Classified TODs are available from the Defense Technical Information Center (DTIC) and unclassified/unlimited TODs are available from the National Technical Information Service (NTIS).

As you read through the pages that follow you may see a field of endeavor where your organization can contribute to the achievement of a specific technical goal. If such is the case, you are invited to discuss the objective further with the Division or Branch identified in Appendix I Organization Chart. Further, you may have completely new ideas not considered in this document, which if brought to the attention of the proper organization, can make a significant contribution to our military technology. We will always maintain an open mind in evaluating any new concepts, which when successfully pursued, would improve our future operational capability.

On behalf of the United States Air Force, you are invited to study the objectives in this document and to discuss them with the responsible Air Force personnel. Your ideas and proposals, whether in response to the TOD, or not, are most welcome.

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SECTION I

MANAGEMENT OVERVIEW

Laboratory Mission

The Flight Dynamics Laboratory (FDL) is part of the Air Force Wright Aeronautical Laboratories (AFWAL), a four-laboratory organization which is part of the Aeronautical System Division located at Wright-Patterson AFB OH. The FDL is responsible for planning, formulating, and executing the USAF technology programs for aerospace vehicles in the technical domains of structures and dynamics, vehicle equipment/subsystems, flight control, and aeromechanics. The FDL maintains a superior technical base by exploring promising approaches in science and technology which will provide options in the development of Air Force systems and prevent technological surprise.

The Flight Dynamics Laboratory carries out the technology integration responsibility for AFWAL and is the lead laboratory for experimental flight vehicles, crew station integration, and the AFWAL Sortie Generation/Integrated Logistics Major Thrust. The FDL is also the focal point for advanced composite and metallic structures, non-nuclear survivability, and lightning hazard protection. The Laboratory directs a full-spectrum technology program covering research, exploratory development, advanced development, and selected engineering development.

The FDL pursues technology assessment, integration and transition, and maximizes program productivity through interaction and review of industry Independent Research and Development (IR&D), and through cooperative and interdependent programs with the Army, the Navy, NASA, FAA, DARPA, other government agencies and organizations throughout the free world.

In-house research and development, using unique skills and facilities, is a strong component of the Laboratory program in order to develop and maintain pre-eminent technical and scientific leadership in selected disciplines, as well as to provide the basis to guide a technically sound contracted program with industry, universities, and research organizations.

Director's Assessment

This year our orientation of technology is shifting to emphasize specific technologies that support the Project Forecast II initiative of AFSC. In that context, the Laboratories' four major technology thrusts are: 1) Hypervelocity Vehicle Technology which has been enabled by the technology advances of computational fluid dynamics, hypersonic aerothermodynamics and flight control, cooling of hot structures, thermal management, escape and propulsion; 2) STOL and STOVL which has been enabled by the technology advances of low speed STOL aerodynamics, advanced structures, autonomous landing guidance and propulsion; 3) Fighter Battle Management which has been enabled by the technology advances of 3-D crew station display, voice enhancement, rapidly reconfigurable cockpit, microprocessor reconfiguration, and crew/vehicle integration; 4) Reliability/Maintainability and Supportability which has been enabled by Fault Tolerant flight control, fracture mechanics applied to electronics, artificial intelligence application, aircraft battle damage repair, contamination avoidance-robotics, cryo-cooler, large space structure, windshield transparency, tire, and integrated brake control. We are also heavily supporting DOD/NASA on the National Aerospace Plane program.

Our specific Project Forecast II OPR tasks, are Rapidly Reconfigurable Crew Station (plus integration of the three other crew station related tasks), Cooling of Hot Structures, STOL/STOVL/VTOL Technology and Hypersonic Aerothermodynamics. We also have a strong interest and support to many of the OCR tasks - principal amongst those are Fault Tolerant Electronics, High Temperature Materials and Ultra Structured Materials.

We are de-emphasizing specific areas of technology because of lower priority and the need to optimize or orient our manpower to support the named emphasis areas: Durability of Conventional Metals and Fasteners, Low Temperature/Low Strain Organic Composite Structures, Rough/Soft/Short Field Landing Gear and Integrated Steering/Braking Control Systems, Air Cushion Equipment Transporter, Atmospheric Lightning Hazards Protection Technology Simulation, Integrated Control in Flight Research, Display Devices, Airframe/Propulsion Integration for Low Observable Fighter Aircraft, Compact Versatile Fighter Aero Technologies and Transonic High Reynolds Number Testing.

We will see the critical strategic application in 6.3 of the Boost Glide Vehicle program in FY87. The AFTI/F-16, AFTI/MAW, AEHP are completed in FY87. The "Survivable Attack" and "Advanced STOVL" programs are contemplated as FY91 starts.

The following accomplishments have contributed to the Laboratory four major thrusts of Hypervelocity Vehicle Technology, STOL and STOVL, Fighter Battle Management, and Reliability/Maintainability and Supportability. The accomplishments in the Laboratory technical disciplines:

<u>Technology Assessment</u> (a) An interdivision cooperative effort to assess selected vehicle equipment technologies (advanced crew escape systems, integral variable displacement fuel tanks on-board detoxification system, jump strut, soft field landing gear, and rough field landing gear) as applied to advanced tactical ground attack aircraft. (b) A design and assessment study of a survivable V/STOL transport and a low-cost, cruise-efficient STOL transport.

<u>Structures and Dynamics</u> (a) Wind-tunnel test demonstration of a fully adaptive external store system on an F-16 model. (b) Proof-of-concept tests of using heat pipe principles within a structural thermal shield to survive high heat flux. (c) Evaluate structural potential of new high-strain composite systems and their impact on aircraft design. (d) A production brazing process for superalloy (Rene' 41) honeycomb panels that involves the cleaning of the panel components to remove all surface oxides, the optimization of the constitutents of the braze alloy to give good fillet flow, and a brazing cycle that greatly improves the fracture mechanics properties of the material. (e) Development of sensors and actuators for the control of the vibrations of large space structures. The hardware will be used in a joint Air Force/NASA/SDI program to assess the performance of techniques to control space structures.

<u>Vehicle Equipment</u> (a) Final laboratory hardware design and fabrication for an advanced landing gear system (ALGS) for the F-16 aircraft

incorporating rough field, soft field, jump takeoff, and improved sink rate capabilities. (b) Final laboratory hardware design and fabrication for an Integrated Aircraft Brake Control System (IABCS) which coordinates nose wheel steering, automatic braking, and rudder commands during takeoff and landing in adverse weather conditions (high crosswind, low coefficient of friction). (c) Laboratory qualification of A-10 aircraft worthy electric brake system (EBS) hardware and high speed taxi tests at Edwards AFB, completion of the Class II modification plan. (d) Technical feasibility and practicality of dynamic scaling techniques to design, fabricate and test small models of landing gear struts and tires. (e) The first forming trials of a portion of a frameless transparency which consists of selective thickening of the transparency and embedded integral fastener hardware along its edge.

Flight Control (a) A workshop which addressed the problem of loss of aircraft attitude awareness, primarily in the single-seat fighter-attack aircraft. (b) A study for F-16 SPO establishing basic requirements for the development of an advanced wa' 'ing/caution/advisory display panel and candidate formats for use with ` panel. (c) Key elements of the prototype Automated Layout Center .ie a quantum advancement in the ability to create an entirely new ,c and to "fly" the cockpit in a simulated mission context within a matter of hours. (d) An advanced flight control/propulsion control system "man-in-the-loop" simulation for a highly coupled Advanced Tactical Fighter Configuration. (e) A manned simulation assessment of the F-16 LANTIRN automatic terrain avoidance system using the LAMARS large motion base simulator.

Aeromechanics (a) An optimized STOL and VSTOL advanced tactical transport concept employing advanced counter-rotating turboprop engines over an externally blown flap arrangement in order to achieve both superior cruise and STOL capabilities. (b) A Parabolized Navier-Stokes (PNS) code revision to model chemistry effects by the addition of an equilibrium-air real-gas model. (c) A study on manned military vehicle configurations with trans-global range using rocket and ramjet power and a glider. (d) An aerodynamic performance and signature characteristics of contemporary and advanced air-to-air weapons carried externally and internally on advanced fighter aircraft configurations. (e) A design and evaluation of interceptor configurations: (1) Long Endurance Subsonic Aircraft with a large number of high-speed missiles (2) A supersonic interceptor (3) A hypersonic interceptor with a radius of action of 1000 nautical miles. (f) Demonstrated advantages of cruise camber control on the AFTI/F-111 for advanced fighter applications.

Our personnel level has been subjected to considerable change with a modest turnover amongst key civilians and higher turnover in the military workforce. New imposed restrictions on staffing have made filling key technical positions, especially at the GS-12 level, very difficult. New Federal personnel system benefit changes (actual and proposed) have made conversion of co-ops and recruits equally difficult. The Gramm-Rudman tax proposal has further exacerbated this impact on the Lab. Our competitive posture with private industry has never been worse.

Our facility picture is being reshaped to emphasize integrated test capabilities in support of new Lab initiatives. Therefore, our MCP program calls for modifications for test integration to B-65 and the B-24/25 complex in FY89 and for full-scale dynamometer development to B-31 in FY89. Curtailment of considerable resource expenditures to maintain and operate our facilities is being pursued under facility modernization through automation, improved operating techniques, and updated laboratory test equipment. A new in-flight facility development "Variable In-flight Simulator Test Aircraft" has started in FY 86 to provide a national facility capable of simulating high-performance aircraft and their control systems beyond the regions of flight that the performance-limited NT-33 can attain. The improvement of our resident wind-tunnel facilities will offer rapid and affordable testing and validation of the Computational Fluid Dynamic codes. The new subsonic Aerodynamic Research Lab (SARL) will offer a unique testing capability to explore a wide spectrum of solutions for future military applications.

Investment Strategy

Our Investment Strategy this year is to support the Project Forecast II Initiative and is a first priority of a list of six priorities. As such, this will emphasize for hypervelocity vehicles: high temperature testing, elevated temperature structural concepts, cooling of hot structures, total thermal management, capsule escape concepts, aerospace tire technology, control technology, airframe/propulsion integration, weapon carriage and separation, performance optimization for propulsion ascent/launch, aerothermodynamics. Also emphasized will be STOL/STOVL/VTOL and associated flight dynamics technologies. The SDI and ADI support will emphasize surveillance platform technology, space system analysis and design, spacecraft cryogenic cooler technology, BGV demonstration, MRRV/ERV Space Defense Initiative Program, and High-Speed Interceptor Aircraft/Missile Technology Integration and In-house Research & Development. Within this framework in our 6.2 P.E. the FY 88 breakout against the Strategic Plan sub goals is: Tactical - 21%, Strategic - 26%, Mobility -5%, Space (SDI) - 7%, Multi-mission Core - 35%, R/M&S - 6%. Within the 6.3 PE the FY 88 subgoal breakout is: Tactical - 56%, Strategic - 17%, Mobility - 2%, Space (SDI) - 4%, R/M&S - 21%.

Specific Investment Strategy guidance following Project Forecast II is: Actively manage in-house research and directly relate to our mainstream effort/emphasis areas (critical mass required), continue to pursue R/M&S work, increase support to space-related technologies, emphasize V/STOL/STOL, increase investment in hypervelocity vehicle technologies, emphasize survivability, orchestrate 6.1, 6.2, 6.3 transitions thru crisp objectives within each work unit (some near-term, others long term), leverage IR&D, and recognize the Air Defense Initiative influence. Support of Inter-laboratory and Inter-Agency joining programs must have a payoff to the Air Force in our mission area and we must be recognized for our effort, compete for Small Business Innovative Research funds where unique strengths exist, and increase contracted procurement package efforts to an amount of $500,000 or more each.

Program Relationships

The Flight Dynamics Laboratory's programs are cognizant of the technologies developed by other Air Force Laboratories and R&T organizations, DOD agencies, NASA, and industry IR&D programs. Evolving technologies must be integrated to obtain the maximum benefit for flight vehicle performance and mission effectiveness. Towards this end the Flight Dynamics Laboratory works actively with other organizations through cooperative programs and data sharing. The Laboratory has liaison offices at the NASA facilities at Ames and Dryden. A list of cooperative programs is as follows:

Advanced Tactical Airlift System Concepts. A joint effort with ASD/XRM to examine concepts that provide tactical airlift capability under various levels of threat intensity and evaluate the feasibility of multiple aircraft type force structures to optimize technology effectiveness.

Tactical Aerospace System Integration. A joint effort with AFATL to investigate the integration of reentry vehicles with the carrier vehicle.

Nozzle Installation Loss Prediction Methods. A joint program with the Foreign Technology Division to develop a computer program to calculate nozzle/afterbody installation losses.

Experimental Modal Analysis and Dynamic Component Synthesis. A joint effort with AFATL to extend vibration modal test and analysis methods so that we can correct, refine, or even establish the analytical structural model with the modal experimental data.

Aircraft Structural Vulnerability in a Nuclear Blast Environment. ASD, AFWAL and DNA are modifying FLEXLODS to simulate air vehicle response to a nuclear blast. A Lab interactive graphics program has proved to be useful for pre- and post-processing, and NASTRAN finite element models are being used in the final design portion of FLEXLODS. This effort will provide ASD with an accurate dynamic loads program.

Bolted Joints in Composite Structures. Participation with NADC in the development of a design guide for bolted joints in composite structure. Contracts with Industry are providing data representative of F-18 composite joints. The Lab effort will develop an enhanced version of the Bolted-Joint Stress-Field Model analysis program.

Post-Buckled Structures. Coordination of Air Force and Navy contracted programs in postbuckled metal and composite panels. The Lab and NADC are exchanging data to enhance the design guide being developed. NADC has also participated in formulating the Lab follow-on program.

Composites Supportability. A jointly funded activity with the Army to develop the composite aft-fuselage for the Army Blackhawk and Air Force Nighthawk helicopter systems to improve the supportability, operational readiness, survivability and weight for both helicopters.

The DOD Metal-Matrix Initiative. The DOD Metal Matrix Program (Air Force, Navy, Army, NASA and DNA) coordinates current and planned metal-matrix work. The Air Force is purchasing 500 pounds of high-modulus graphite fiber to be converted into sheet and plate stock for the test program.

Ballistic and Laser Vulnerability and Hardening. Joint effort with the JTCG, other DOD agencies and industry to evaluate the vulnerability of the current fleet structure to ballistic and laser damage and the development of concepts for structural hardening.

DOD/NASA Composites Interdependency. DOD/NASA Composites Interdependency Group coordinates the development programs among all the services and NASA to insure that there is no duplication of effort, to exchange data and to identify needed programs.

testing. The NASA Langley 16-foot Transonic Dynamic Wind Tunnel is the best facility in the United States to perform flutter suppression testing. Since 1977, eight AFWAL-sponsored wind tunnel entries have been made in that tunnel. NASA has approved an additional entry for FY87.

Joint Live Fire Program. A joint tri-serivce program being performed for the Office of the Undersecretary of Defense to assess the vulnerability of front-line weapon systems like the F-15 and F-16 aircraft. The ballistic test ranges of the three services are shared in accomplishing the objectives.

SURVIAC. A new Department of Defense Information and Analysis Center specializing in survivability and vulnerability. Technically managed by the Lab and guided by a steering committee consisting of engineers and managers affiliated with the JTCG/AS.

Atmospheric Electricity Hazards Protection. A cooperative national effort with the Army, Navy, DNA, FAA and NASA to develop and demonstrate balanced electronics and avionics subsystem hardening techniques against natural atmospheric lightning and static electricity, and which complement and integrate related nuclear electromagnetic pulse and electromagnetic interference protection.

Air Cushion Equipment Transporter Technology. A joint program with the Canadian government to develop and demonstrate the feasibility of an air-cushion-borne towed platform to move tactical aircraft and equipment up to 60,000 pounds over rough or soft terrain and battle damage repaired airfields.

Integrated Closed Environmental Control Systems. A joint program with the Canadian government to develop and demonstrate in the laboratory a microprocessor-based, vapor-cycle type, closed loop environmental control system which uses limited bleed air for crew fresh air and pressurization. Fuel is used as the ultimate heat sink.

Lightning/NEMP Measurements Program. A joint in-house program with the Air Force Weapons Laboratory, Naval Research Laboratory, FAA and NASA Kennedy Space Center to acquire experimental data on the characteristics of lightning and the effects due to coupling of atmospheric lightning cloud-to-ground discharges and direct strikes with aircraft-airborne electrical and electronics subsystems.

Crew Escape Technology (CREST). A cooperative program with the Aerospace Medical Division and the Armstrong Aeromedical Research Laboratory to define, develop and demonstrate (in a system concept) critical subsystem technologies including a controllable thrust seat catapult, crewmember restraint, windblast protection, selectable thrust ejection seat propulsion and microprocessor-based digital flight and thrust vector control for trajectory control and seat/man stability assurance.

Electric Aircraft Brake. A joint program with ASD to develop and demonstrate the feasibility and assess the performance capabilities of an electric brake system for the A-10 aircraft. Performance evaluations will be accomplished in the AFWAL Landing Gear Development Facility and during aircraft ground testing.

Aircraft Battle Damage Repair. A parallel development activity with the Human Resources Laboratory, Aeronautical Systems Division, Air Force Logistics Command and other AFWAL Laboratories to develop damage diagnostic and rapid repair concepts for flight control systems allowing them to be safely flown with failed elements or rapidly repaired due to the ability to quickly isolate failed or damaged line-replaceable units.

Integrated Design Tools. Coordinated effort with Structures and Aeromechanics Divisions, the Propulsion Lab and NASA. The intent of this effort is to develop a generic computer-aided control system design and analysis environment that uses expert system technology. This tool will be used to design Integrated Flight Propulsion Structural Control (IFPSC) systems which enhance total system performance.

Aeroservoelasticity (ASD). An effort using Structures Division programs ADAM and ASTROS, NASA/Langley's Functional Integration Technology program, and Aeromechanics Division to generate aeroelastic models suitable for flight control and analysis, and theoretical investigation into ASE modeling methods.

Aerodynamic Control at High Angle-of-Attack. A joint program has been started with NASA/Langley to conduct wind tunnel tests of forebody devices to define the useable forces and moments associated with nose vortex control. A related effort starting in 1986 is to investigate on a broad base the potential of vehicle control through vortex manipulation. Future work will be directed at validating the most promising concepts at high Reynolds number and full-scale flight tests.

High-Angle-of-Attack Stability and Control. A coordinated effort with the NADC and NASA/Langley efforts to develop design methods and guidelines for tactical aircraft designed to operate in the high-angle-of-attack regime (30 degrees and higher) which can be used during the preliminary design phase of highly maneuverable vehicles.

Robust Control Theory. Cooperative computational efforts in robust control theory with NASA. Results of the in-house studies are exchanged on a regular basis.

Large Space Structures Pointing and Shape Control. Interfaces with DARPA, AFSTC, AFRPL, NASA and industry specialists are maintained so that the space controls community can see the advancements being made. The antenna structural model will form the basis for a simulation to be performed at the Rocket Propulsion Lab.

Flying Qualities Requirements. A coordinated program to upgrade military flying qualities requirements is underway with ASD/EN, AFFTC, Navy, and Army. The aircraft and flight control industries, and British, French and German sources participate through IRAD and data exchange agreements. The Navy is an active participant in the development of Vertical and Short Takeoff and landing handling qualities requirements, and the Lab is coordinating with the Army's rework of rotary-wing handling requirements.

Air Mass Reference Systems. A cooperative effort is being conducted with NASA Dryden to flight test evaluate flush mounted air data sensor concepts to form a baseline for making decisions on control data system developments for applications such as hypervelocity vehicles, supermaneuverability, and non-intrusive air data systems.

Smart Actuators. A joint program with the Navy is envisioned to develop "Smart Actuators" to minimize the complexity of the interface of multiple actuators with the rest of the system by judicious application of micro-processors. This program represents a step closer in achieving reconfigurable flight controls that enhance safety and combat survivability.

Rapidly Reconfigurable Crewstation. A Project Forecast II initiative jointly with Avionics Laboratory to provide the ability to create an entirely new cockpit and "fly" the cockpit in a simulated mission context within a matter of hours. The system will feature software that automatically transitions display images to real time graphics, allowing design by users with no software skills. It employs advanced hardware concepts such as panoramic display surfaces, voice control and audio holography. Full scale development will begin in FY87 leading to a total system demonstration in FY91. A proof of concept prototype, limited to one display surface, will be demonstrated in 1987.

Cooperative Operations Effectiveness (COE). An exploratory research program to identify, quantify, and evaluate mission payoffs afforded by increased, real-time cooperation among the members of an attacking flight and its support elements through distributed decision making, task allocation, and redundancy exploitation. This program supports the joint Flight Dynamics and Avionics Laboratory ICAAS Program.

Multivariable Control Theory. An on-going joint coordinated effort with AFIT to evaluate, extend, and verify current control system design techniques. It involves AFIT Professors J.J. D'Azzo and C.H. Houpis and selected AFIT M.S. and PhD students.

Integrated Control and Avionics for Air Superiority (ICAAS). A cooperative effort with the Avionics Laboratory to develop and demonstrate a functionally integrated control system to improve effectiveness of air superiority fighter aircraft. It involves target sensors, fire control, flight control, aircraft performance, pilot interface, automatic control, and weapons. Other participants include the Armstrong Aerospace Medical Research Lab, Air Force Armament Lab, Air Force Flight Test Center, and the F-15 Systems Program Office.

Aviation Behavioral Technology Development. A three-year study program to collect, collate, and validate aviation behavioral technology for reducing aircraft accidents, particularly those with pilot error or pilot-induced caused factors. An important objective of the program will be the development of criteria which minimize the economic impact on aircraft and human performance capability or operational flexibility. This contract has been let under a joint USAF/FAA agreement to investigate common areas of concern.

Cockpit Automation Technology CAT). A joint AFAAMRL/AFWAL advanced development program developing a new crew system process which determines the best use of cockpit automation and assures the most efficient use of the pilot. Innovative design methods will be applied in defining the crew system

Composites Design Guide. Joint effort with NASA, Army and Navy to publish the Advanced Composites Design Guide under the auspices of the DOD/NASA Composites Interdependency Panel.

Precision Structural Joints for Spacecraft. NASA Marshall and NASA Langley are cooperating with the Lab in the development of precision (no slop) structural joints for deployable antennas. Shuttle-based flight experiments are planned for the late 1980's.

Vibration Control of Space Structures (VCOSS). NASA Marshall and the Lab are developing hardware for controlling the vibration of structural modes in large, flexible spacecraft. The first phase will identify control system and actuator and sensor hardware for a typical surveillance spacecraft. The second phase will be full-scale hardware testing on the NASA Space Technology Experiment Platform in cooperation with NASA Langley and Marshall.

Transonic Unsteady Aerodynamics. An MOU with NASA to develop the computational transonic unsteady aerodynamics capability needed for the aeroelastic and aeroservoelastic analysis of current and emerging aircraft. Coordination meetings will continue with Langley and Ames to complete the joint efforts to extend and improve the XTRAN3S computer code and its improved successors.

Weapon Bay Cavities. The Lab and NASA Langley are conducting a wind tunnel test program to define the static and acoustic environments in cavities exposed to supersonic flow.

High-Temperature Test Techniques. NASA Lewis, AFWAL/PO and the Lab are developing devices to measure structural strain at high temperatures. The AFWAL/PO program is developing a fiber-optic strain-sensor for measuring steady-state strain levels on rotating turbine engine components at 1200 °F. The NASA program is developing a strain measurement sensor for application on non-rotating turbine engine components at 1600°F. The Lab program is trying to reach 2000° F for full-scale structural tests. The Lab and NASA (Langley and Dryden) are jointly determining the national requirements for new test techniques and facilities for thermal/structural tests of full-scale air-frames.

Aircraft Fuel Tank Technology. Our fuel tank test facility supports development of integral fuel tanks for future fighter/attack aircraft and to evaluate the performance of adhesive bonding for composite fuel tanks. Future activity will be in the area of co-cured composite fuel tank structure and the F-18 fuselage tank.

Structural Optimization. An information exchange program has been established between the Lab and the UK Royal Aeronautical Establishment in structural optimization. RAE interests are in mathematical programming methods. The Lab methods based on the optimality criterion approach have been developed and their performance investigated. The exchange of information helps both organizations develop algorithms for designing optimum aircraft and spacecraft structures.

Active Flutter Suppression. NASA has contributed to the theoretical development of flutter suppression and the verification through wing tunnel requirements for advanced fighter aircraft, focusing on both the tactical air-to-ground and air-to-air missions. This program is being managed by the Armstrong Aerospace Medical Division.

Pilot Associate Program. The Pilot Associate program sponsored by DARPA and directed by AFWAL/CCU is a joint effort with the Avionics Lab. The primary thrust of the Pilot Associate Program will be directed toward developing and evaluating machine intelligence technologies for transition to service applications on combat aircraft in the post-1993 timeframe. The program will create a development environment to apply AI technology to help the pilot maintain situation awareness, plan mission and tactics, navigate, monitor internal systems and other tasks required to accomplish the mission.

Multifunction Flight Control Reference System (MFCRS). An F-15 flight demonstration originally defined by a joint effort (Multifunctin Inertial Reference Assembly - MIRA) with the Avionics Lab. It will be followed by a demonstration flight test of an Integrated Inertial Sensor Assembly (IISA) now being defined in a joint program with the Naval Air Development Center (NADC).

High Pressure/Low Profile Actuation. Joint program with the Propulsion Lab to develop 8000-psi rotary or linear actuator for use in thin wing, variable camber wing, or other advanced aircraft innovations requiring small actuating devices.

Fiber Optic Sensor (Aircraft and Space). Joint program with NASA to fund Jet Propulsion Lab development of fiber optic rate, point, and control sensors for boost vehicles, space structures, and aircraft.

F-15 Aircraft Model Identification. Joint program with NASA to instrument/flight test an F-15 for the purpose of improving aeroservoelastic modelling techniques s applied to stability, control and handling quality predictions for advanced flexible airframes.

QF-106 Target Drone Simulation. A joint program with the Armament Division's Deputy for Range Systems to conduct a hybrid simulation of the QF-106 drone and its newly developed Automatic Flight Control System. Simulations and subsequent analysis will assess drone performance throughout its maneuvering envelope prior to flight control hardware fabrication and full-scale flight testing.

Supermaneuverabilty. A program is being developed to expand the operational flight envelope for fighter aircraft. Included are flow field management (force and moment generation, dynamic lift), weapons issues (point and shoot, launch angles of attack of 40 or more), avionics (situational awareness data), and control (integration of propulsion/flight control, departure prevention). Currently involved government organizations are DARPA, NASA, NASC, AFOSR, AFATL, German Ministry of Defense, NLR (Netherlands), NAE (Canada), AFWAL (AA, POT, FIM) and AMRL.

Airframe/Propulsion System Integration. A cooperative program with NASA/ARC, LaRC to assess the benefits and liabilities of highly integrated inlets and exhaust nozzles coupled with low signature and STOL requirements in advanced tactical aircraft and to apply and validate enhanced state-of-the-art design procedures.

Airframe/Weapons Integration. A cooperative effort with Navy, DTNSRDC, NWC, NASA/LaRC, Armament Lab, and AEDC to evaluate the aerodynamic and signature impact for various external air-to-air (AIM-120A and AIM-9) weapon integration configurations on an advanced supersonic fighter. The carriage and separation of air-to-air weapons from internal bays is being investigated jointly with AFATL and industry.

Store Separation Aerodynamics. A joint program with NASA/ARC, AFATL, Navy, and industry to predict the aerodynamics of stores in proximity to aircraft.

Advanced Multifunction Multiplane Exhaust Nozzle Integration. A coordinated program with AFWAL/APL and NASA/LaRC to develop a technology base for integration and utilization of exhaust nozzles with pitch and yaw-vectoring and with thrust-reversing for a post-1990's aircraft.

Computational Fluid Dynamics. A cooperative research program on the numerical simulation of F-16 aircraft with NASA/Ames Research Center. The scientific exchange program between NASA Research Centers (Ames, Langley, and Lewis) has been strengthened based on the guidelines stipulated by the 1977 Memorandum of Agreement.

Aerodynamic/Propulsion Missile Demonstrator. A joint effort with Aeropropulsion Laboratory, Navy, and NASA to investigate the best combination of advanced aero-configuration missiles with advanced propulsion systems.

Mission Adaptive Wing (MAW). A joint program with NASA to provide design criteria and technical confidence for smoothskin variable camber wing technology in future systems. Industry developments in automatic flight control modes will be demonstrated during MAW flight tests.

Hypervelocity Research Vehicles. A proposed joint NASA/USAF flight demonstration program for the mid-1990s. A research vehicle, capable of launch from the Space Shuttle or from the ground using existing booster systems, will conduct flight research on critical technologies for orbital reentry, on-demand launch sortie vehicles, and aero-assisted orbital transfer vehicles.

Boost Glide . Configuration concepts being explored using the NASA/LaRC hypersonic wind tunnels as well as the USAF/AEDC facilities. Analyzed data is being forwarded to AFFTC for development of BGV flight simulation using the shuttle simulator.

Advanced Strategic Reentry Vehicle Aeromechanics Technology. An MOA, jointly funded with BMO, to provide technology for solution of a variety of problems associated with strategic reentry vehicles. The Flight Dynamics Laboratory supplies in-house support to the tasks of augmented roughness efforts, boundary layer stability, maintenance of a series of flow field prediction codes, and development of wind tunnel data using AFWAL facilities.

PNS Flow-Field Program. The AFWAL-sponsored PNS Workshop has provided the interaction among users which accelerated this aerothermodynamics method to the status of an industry standard at over 60 installations.

Boost Glide Vehicle (BGV). Cooperative wind tunnel test programs to evaluate BGV concepts. MOUs coordinated with NASA/Ames and LaRC. NASA/GSFC is assisting with planning for Tracking and Data Relay Satellite System use for the BGV Technology Demonstration program, and an MOU is being worked. WSMC, BMO, and AFFTC are closely working with BGV for the Technology Demonstration Program Flight Test - an MOU is in coordination. On-going coordination and testing is underway using AEDC wind tunnel facilities.

X-29A. A joint program with NASA/DARPA to conduct the follow-on program addressing high angle of attack effects on performance. The Flight Dynamics Lab has overall program management responsibility.

SECTION II

TECHNOLOGY ASSESSMENT

Investment Strategy and Relation to Lab Strategic Plan

Technology Integration and Assessment has three major elements which are necessary to successfully perform scenario based technology evaluation. These are a concept data base, development needs based on threat/projected requirements, and mission/concept analysis. A key element is to develop and maintain a working interface with product-developing organizations, product using organizations, Air Staff, and with other FDL Divisions and Labs. This approach provides a perspective which brings together the opportunities of technology with projected user requirements and future systems needs under the real-world constraints of conceptual systems synthesis and analysis. Technology Assessment provides a technology driver-oriented systems concept data base. The data base is populated with concepts from in-house and contracted studies, from other government studies and from IR&D.

Threat projection, requirements formulation, and mission analysis are iterative with the concepts synthesis data base. Projections of technology gains and future requirements must be converged. To do this with any credibility, it is vital to have a data base which reflects technology opportunity. The objective is to answer the question "How do you decide which technologies to work?" The process involves inputs from mission needs, ideas, users, and new technologies; and the output is promising technologies and technology voids which are then used by the Laboratory and major thrusts for planning purposes.

In this year's planning cycle, we will follow a balanced approach to technology investment where the needs of the users and the opportunities afforded by advanced technology are brought together for the twofold purpose of identifying high-payoff technologies and to provide advocacy rationale for technology applications in a systems context. In selecting conceptual systems that will impact future Air Force capabilities, the guidance provided by Project Forecast II was used extensively. Specifically, the aeronautical systems were selected as a starting point for determination of the vehicle characteristics mission-effectiveness and technology assessment. Specific efforts will be initiated to insure that the aeronautical systems are being evaluated to determine mission-related technology figures of merit and to assess applicable technologies to determine the drivers. The efforts previously initiated and/or planned using earlier guidance were assessed and reoriented (where applicable) to align with Forecast II objectives. Additionally, the "requirements pull" has continued to review and use the motivating factors of policy and doctrine of AirLand Battle 2000/Concept 21, Air Force 2000, Laboratory investment strategy, Vanguard, and other applicable guidance as included in SDI, ADI, R&M/L, NASP, etc. This guidance has led to a series of individual efforts that have been aligned in selected Division goals.

Specific Goals and Technical Approaches

GOAL 1: Global Tactical War Fighting

OBJECTIVE: Obtain a balanced assessment of the total worldwide tactical needs and to understand the key operational and system drivers as a function of given conditions and opportunities of future development. This results from the perceived growing requirement for the Air Force to respond to worldwide situations in an effective manner. This includes both the NATO environment and third-world areas such as the Middle East, South and Central America, and Africa which are characterized by intensity of the conflict, limit of prepositioning of forces, and the sophistication and availability of facilities. The ultimate concern is the role of technology relative to the global tactical perspective.

APPROACH: A series of efforts will be conducted to investigate many of the major factors that contribute to the tactical warfare area. These will be explored in the context of the immediate tactical mission accomplishment and the necessity to exert a "Tactical Presence" on a global or worldwide basis as future crises may develop. These efforts will deal with the issues of timely deployment to the crises areas, intratheater employment, logistics, and supportability as a function of the operational issues and levels of conflict intensity. Specific efforts that will be conducted in support of this goal are as follows:

a. Fighters

(1) Air Battle 21: Investigate the nature of future air combat. Emerging technologies are creating a major expansion in the types of air-to-air engagements. Long-range capabilities in weapons and sensors, high-speed capabilities in aircraft and information processing, along with low observables technology and advanced EW systems, will cause air forces to develop new forms of combat to supplement the classical tactics currently employed. This effort will examine future scenarios and missions, system and technology options, operational concepts and tactics, and potential threat responses to negate our technology advantage. It will require the use of new third-generation digital air combat simulation models as well as limited man-in-the-loop simulation by TAC aircrews to establish credibility. System definitions include aircraft, C3I networks, spacecraft, and weapons. Advanced fire control systems with multiple target track and BVR, launch and leave multiple missile engagements will be considered. Tradeoffs will be conducted for missile firepower characteristics. Reactive threat capabilities in an attempt to countermeasure BVR missiles will be evaluated. Aircraft interface issues will include missile carriage integration, sensor integration, and harmonization of emphasis of aircraft capability with that of the weapon system, the avionics, and aircraft performance.

(2) Close Air Support/Defense Suppression: Develop conceptual air vehicle designs and to define/assess advanced technology alternatives for the suppression of enemy air defenses (SEAD). Determine those SEAD concept design characteristics which can increase the overall effectiveness of TACAIR close air support/battlefield air interdiction (CAS/BAI) forces. Both manned and unmanned SEAD concepts will be designed and evaluated as well as force mixes of the two in support of CAS/BAI against the projected year 2000 threat in Central Europe and Southwest Asia and will include investigation of the Forecast II system "Tactical Low Cost Drones."

(3) Air Combat Analysis: Develop an improved in-house capability to assess technologies related to beyond visual range (BVR) and close-in air combat (CIC) engagements. This will focus on low-cost man-in-theloop (MITL) air-to-air combat simulation. The low-cost MITL simulation will be developed using the Advanced Air-to-Air System Performance Model (AASPEM), low-cost manned interactive stations such as the Manned Combat Station, advanced computer technology, and a distributed processing concept. The simulation will address subsonic, transonic, and supersonic performance, and will represent aircraft with decoupled aerodynamic and propulsive controls as well as unusual flight regimes. Weapons considered will include long/medium range air-to-air missiles, short range air-to-air missiles and guns. Currently available software will be used where possible, modified and/or simplified as required for real-time operation. Emphasis will be placed on providing the minimum level of fidelity required to conduct comparative analyses throughout the program.

(4) Survivable Fighter/Attack Technology Alternatives: Determine the value of and technology needs/opportunities of high-altitude atmospheric delivery of tactical weapons for the air interdiction mission projected for the 2010 time period - both aircraft and weapons. Two scenarios representing high and medium threat intensities will be developed from which mission requirements will be developed. Conceptual weapon system options will be based on the mission requirements for varying degrees of technology risk. Perform survivability and effectiveness analysis for each of the conceptual weapon system options and technology assessments on the most promising concepts.

b. Multi-mission

(1) Forecast II Design and Analysis: Determine preliminary vehicle characteristics and mission effectiveness for several selected aeronautical concepts from Forecast II, using a process of conceptual design and mission analysis in the context of projected scenarios. The establishment of technology goals requires quantitative definition of the vehicles for various projected mission requirements. Among the concepts which may be included are the Supersonic V/STOL Tactical Aircraft; the Multi-role Global Range Aircraft; the High-Altitude, Long-Endurance, Unmanned Aircraft; Hypersonic Interceptor Aircraft; and the Multi-mission RPV. Concept arrangement, vehicle sizing, and performance characteristics will be determined for several mission profile options. Sensitivities to variations in requirements, such as payload and range, will be calculated. Sensitivity of mission effectiveness to variations in technology capabilities will be used to establish technology goals. Alternate concepts of operation will be explored to assess the maximum payoff for technology. Each concept will be evaluated in terms of mission effectiveness parameters that include survivability, lethality, cost and flexibility.

(2) LandAir Battle 2000: Investigate operational concept and associated technologies which are required to provide a global capability for future tactical air forces. It will utilize results from the Global Tactical Presence (GTP) effort and investigate operational concepts and technologies which may shape the global capability of future tactical Air Force. The Global Tactical Presence effort studied six scenarios which relate to four of the six Unified Command theaters: the U.S. Central, Southern, Readiness, and

Pacific commands. These studies have identified certain operational deficiencies in deployment, employment, and support of the present tactical air force. The LandAir Battle 2000 (LAB 2000) investigation will emphasize the employment phase of GTP. New air power concepts generated from LAB 2000 will be synthesized and tested against traditional air operational concepts.

(3) Advanced Propulsion Technology Assessment: Isolate and assess the impact of various levels of advanced propulsion technology in selected mission areas. A wide range of applications will be examined including: CONUS Interceptor, Survivable Attack Fighter, Air-to-Air Supercruise, Land-Air Battle Aircraft, Air-to-Surface Aircraft. These concepts will be prioritized and aligned with Forecast II systems. The initial study effort will address the Survivable Attack Fighter and may be expanded to include study of Air-to-Surface Missiles as appropriate using a carefuly measured blend of speed-altitude performance, low observability, ECM/ECCM, advanced fire control, and advanced weaponry. This will challenge aircraft technology advances in: propulsion, structures, aerodynamics, flight/fire control, avionics, and vehicle equipment.

c. Airlift

(1) Advanced Tactical Airlift: Progress on the tactical airlift effort includes the in-house development of notional tactical transport missions, the concept design and parametric analyses of a candidate VSTOL configuration, a survivability and effectiveness analysis in the context of the notional missions, and an assessment of the critical vehicle/survivability technologies. The inhouse program has been expanded to include cooperative efforts with other Lab Divisions, NASA, APL, and a joint contracted effort with ASD/XR. A number of conceptual tactical transports employing various technology features will be evaluated and Figures of Merit will be accumulated. The conceptual transports will be evaluated in both wartime and peacetime scenarios and will include consideration of various threat intensities.

(2) Low Intensity Conflict (LIC) Transport Technology Assessment: Identify the technology opportunities and needs as driven by low intensity conflict requirements, identify the operational needs and the corresponding technology voids and provide a rationale for technology development planning. Project Forecast II has identified a "Covert/Clandestine Aircraft for Counter Terrorism", and additionally CINMAC has expressed interest in the specific area. The investigation will develop notional missions as the design and analysis medium for both a medium and low threat environment and will develop solutions of low cost vehicles, covert/clandestine vehicles and high-reliability vehicles. The product of this effort will provide focus on the Forecast II systems as to further definition and the determination of the essential technologies to provide the required capability. Technologies that are currently considered essential are propulsion, materials/structures, manufacturing, and low-cost observables/avionics. These technologies will be assessed relative to survivability cost-effectiveness vehicle performance and technology maturity.

<u>MILITARY PAYOFF</u>: The payoff will be a technology assessment that identifies critical technology capabilities, including military effectiveness, quantification of performance parameters, robustness, development status,

risk, system integration requirements, and system transition issues. Determination of those technologies for Suppression of Enemy Air Defenses which can be applied to manned/unmanned air vehicle concepts so that their utility can be evaluated. Air Combat Analysis will provide the ability to analyze many-on-many air combats with a level of realism not previously possible. Forecast II Design and Analysis will provide quantified determination of essential technologies and the required levels of capability to implement selected Forecast II systems. Land Air Battle 2000 will provide information essential to planning and assessing future detail technology development programs.

GOAL 2 Control of Space

OBJECTIVE: Investigate and assess the technological and operational issues and considerations associated with the nonnuclear military use and control of near-earth space. The primary concerns are with basing, launch, orbital and recovery survivability, and weapon(s) use and delivery in selected non-nuclear strategic and tactical scenarios.

APPROACH: Efforts will be conducted to investigate the major factors that contribute to the non-nuclear tactical use of low-earth orbital space and the military value and methods for the control of this space. Efforts that will be conducted in support of this goal are as follows:

a. Tactical Aerospace Assessment: Determine in a parametric manner the value of tactical aerospace operations. Focus effort upon the problem of aerospace operations from a low earth orbit and upon the preliminary design, system synthesis and analysis of the maneuverable reentry vehicles, their support systems and payloads. The vehicle housing the reentry vehicles will not be considered. The effort will culminate with the definition of the value and requirements for a low-earth orbit aerospace operations system in terms relative to design, effectiveness, survivability, and technology parameters.

b. Tactical Aerospace System Integration: Provide data and interface information for integration of the reentry vehicles with the carrier vehicles. Previous Tactical Aerospace Assessment efforts have established baseline designs of reentry vehicle concepts. This effort will investigate the integration of these concepts with the carrier vehicle in areas of payload volume versus weight, packaging shapes, fixed equipment, crew workload, system operating time, and physical interfaces such as electrical, hydraulic, pneumatic power considerations.

c. Methodology for Space System Design and Analysis: Development/collection/compilation of the methods to provide the capability to design and analyze space and transatmospheric vehicles. This includes the capability to size space vehicles for orbital, suborbital, and reentry operations, aerodynamics, weight, cost, stability, and control. The methods will interface with the completed Integrated Design and Analysis System. Phase I of this effort will develop the needed methodology for the reentry configurations. Phase II effort will develop/collect/compile the methods to provide the specific capability to design and analyze transatmospheric vehicles in the hypervelocity cruise and launch modes that incorporate air-breathing propulsion.

MILITARY PAYOFF: The military payoff will consist of the definition of orbital weapon systems targeting and payload requirements, fast response, and mobile target options and augmentation to the rapid deployment force. Additionally, the effort will aid the understanding of the military value of such systems in terms of mission effectiveness and cost, technology requirements and provide a focusing of Laboratory technology effort.

GOAL 3 Multi-mission Core Technology

OBJECTIVE: Develop and integrate five methodology areas (design, vehicle characteristics prediction, mission analysis, operational effectiveness, and cost effectiveness), develop understanding to choose the most appropriate methods, and to develop the knowledge and experience to properly interpret the results.

APPROACH: Efforts will be conducted to develop methods to allow quick and accurate prediction of design, effectiveness, survivability, and cost parameters:

a. Provide analysis support including any or all of the following: (1) an in-depth assessment of current or projected U.S. military capability to perform assigned missions (2) the identification and quantification of mission requirements and (3) the identification and evaluation of alternate courses of action. These include system effectiveness analyses for night attack aircraft and survivability analyses of aircraft supermaneuverability.

b. Advanced Weapon System Requirements: Develop first-order-level analysis methods which will provide the capability to rapidly conduct effectiveness analysis of concepts incorporating advanced technologies. Thoroughly review existing methods and data bases identifying strengths and shortcomings for each. Determine the methodology requirements to ensure that the approach selected is sensitive to all key parameters, including aircraft and weapon performance, advanced sensor (radar, IRST, etc) capabilities, advanced avionics, ECM, tactics, terrain, and weather. The selected effectiveness analysis procedures will be developed and the required data base assembled.

c. Computer Updates and Improvement: Our computer-aided design system uses a dedicated computer to provide the extensive graphics used in the design process. Since its installation, the computer usage has increased and additional disc storage and memory has been added. However, the increased use of color graphics and the number of users will saturate the CPU by 1988 and therefore a replacement of the CPU is planned for FY88.

d. Design Analysis Prediction Methods: Methods are being pursued to: (1) develop a computer program to calculate nozzle/afterbody installation losses, with acceptable accuracy, in a timely manner, given a fairly detailed description of the nozzle/afterbody configuration, (2) develop an RCS prediction method, design guide, and computer code and users manual that are applicable to conceptual design of aircraft with wide-ranging RCS levels. Conceptual designs of low-signature flight vehicles are dependent upon a method which allows the designer to predict the RCS at the conceptual design level. Systematic methods for such predictions are not currently available.

MILITARY PAYOFF: The improved methodology would enhance the capability for conducting the in-house conceptual design studies and the validation of contracted studies. These methods will be available for use by source selection evaluation teams as well as other Air Force and government organizations. Additionally, development of methodologies will provide a quantified assessment of the probability of achieving military objectives in future conflicts under conditions of large uncertainties. The development of methods and techniques is a continuing goal which must be advanced with advancing technologies; however, the efforts described here will be completed in fiscal year 1991. This effort will result in a methodology for use in rapid evaluation of the overall effectiveness of advanced weapons systems under realistic conditions and employment doctrine to identify promising technologies and concepts.

SECTION III

STRUCTURES AND DYNAMICS TECHNOLOGY

Investment Stragegy and Relation to Forecast II and Laboratory Strategic Plan

Structures and Dynamics Technology focuses on FORECAST II, the Laboratory Strategic Plan, new initiatives in Hypervelocity Vehicle Technology (HVT), and the Division Planning Areas.

With respect to FORECAST II, we see major roles for innovative structures technology in several proposed systems and technologies. We will play leading roles in the following technologies: PT-15, Adaptive Control of Large Arrays; PT-16, Smart Skins; PT17, High Temperature Materials and Structures; PT-18, Broad Spectrum Signature Control; PT-21, Cooling of Hot Structures; and PT-22, Ultra-Light Airframes. FORECAST Systems which will receive the most emphasis are: PS-01 Intrathreater VSTOL Transport; PS-04 Supersonic VSTOL Tactical Aircraft; PS-06 Hypersonic Interceptor; PS-18 Long-Range Boost-Glide Vehicle; and PS-23 Aerospace Plane. The Division is well-positioned to support all of the technologies and systems for all subsonic aircraft, supersonic aircraft and satellites; however, we are continuing to divert resources from these areas to support the hypervelocity technologies and systems.

With respect to the Laboratory Strategic Plan, we are addressing "In-House Research and Development" by striving toward centers of focused in-house R&D in: high-temperature fatigue and fracture; structural analysis and automated design; vibration (modal) testing of moderate satellite structures (< 15 meters); the coupling of structural dynamics with aircraft flight controls (aeroservoelasticity); and the combined structural and thermal, dynamic testing of full-scale vehicles and components for high-temperature vehicles. We are addressing "Technology Development" by developing criteria that we employ to maintain a balance between in-house R&D and the use of our facilities and manpower to support basic research, technology development, systems development and operational commands. We are addressing "Technology Integration" by joint planning of the 6.1, 6.2 and 6.3 programs of branches along the five Division Planning Areas. For example:

Investments in Division Planning Area 1, Survivable Structures, are decreasing slightly. Nevertheless we are concentrating on repair, where we estimate that we can achieve a 50% reduction in the time necessary to repair battle-damaged structure for 75% of repairs. For fighter aircraft with external stores, adaptive flutter suppression could double the speed for flutter onset for certain critical store combinations and allow safe carriage in high speed, low level flight.

Investment in Division Planning Area 2, Advanced Aeronautical Structural Concepts, is also decreasing slightly. We estimate that we can achieve a 10% reduction in the weight of today's aluminum structures through new low density alloys. Using graphite/epoxy composites on 50% of an advanced fighter structure could result in 20% weight reduction from today's baselines. High temperature and high strain organic composites are ready for Advanced Development which will allow their use at Mach numbers above 2.2, with even more weight reduction over graphite/epoxy.

Investment in Division Planning Area 3, Aircraft Structural Integrity, also is slightly decreasing. We are concentrating on supportability improvements to result in 50% reduction of structural inspection costs for advanced fighters by allowing (at least) doubled inspection intervals for laminated metallic and organic composite structures.

Investments in Division Planning Area 4, Spacecraft Structures have increased dramatically. We need to achieve structural weight fractions as low as 10% for manned, maneuverable transatmospheric vehicles. Carbon-carbon airframes can be developed on boost-glide, maneuverable reentry vehicles. For large surveillance satellites, reduction of vibration levels to sub-micron levels will be possible by the late 1980's with the tripling of lifetimes to 15 years by integrated active and passive control of vibrations.

Investments in Division Planning Area 5, Structures and Dynamics Technology Base are holding steady. It is essential to maintain a cadre of structural experts in the Air Force with the facilities necessary to lay the foundation for future weapon systems and solve problems of today. Technology Base investment will result in improvement in the Air Force's capability to analyze, understand, and improve the structural performance of its aircraft fleet. Flight-induced loads are changing drastically as aircraft enter new maneuver regimes, and the future's burgeoning computer capabilities must be employed to design future weapon systems to withstand those loads. Increased engine power and supersonic weapon-delivery will cause substantially higher levels of turbulence, noise, buffet, and resulting vibrations to the aircraft and its internal and external stores. At the same time, aircraft wings may become even more flexible to achieve the required combat maneuver rates using leading and trailing edge control surfaces while placing increased emphasis on preventing aeroservoelastic instabilities. All of the factors point to new flight regimes, new loading conditions, new kinds of aircraft, new kinds of analyses and tests and the need for a technology base of experts who can move from a solid foundation to react to new conditions.

Specific Goals and Technical Approaches

Goal 1: Survivable Structures

Objective: Low Observables Demonstrate an order of magnitude reduction in radar cross section with RAM/RAS for fuselage structures (1989) and fighter structures (1990); demonstrate an order of magnitude reduction of radar and infrared detectability for high-temperature nozzles (1988) and high-temperature reentry structures (1992). Ballistic and Laser Vulnerability and Hardening Analyze and test composite airframe structures for ballistic impact, and develop structural concepts with increased ballistic survivability (1988). Develop a design guide for composite integral fuel tanks which resist ballistic damage (1989). Extend vortex arc quartz heaters to full-scale simulation of laser radiation during structural tests (1988); measure the response of current airframe structures to combined loads and laser radiation and develop hardened concepts (1988); complete the development of an efficient structural/thermal analysis program to be used to predict laser-vulnerability for current and future generations of airframes (1989). Structural Repair Develop and demonstrate rapid repair techniques for service-damaged and battle-damaged composite structures; complete the composites repair guide (1989). Short/Rough/Damaged Runways Improve the AGILE data reduction system and extend the AGILE facility to simulate wing lift, lateral loads, drag loads and braking (1988); demonstrate lightweight, corrosion-resistant carbon/carbon structures for STOL nozzles (1988). Develop methods to predict STOL propulsion noise for the prevention of sonic fatigue in secondary structures (1990). Flutter Suppression Complete the flight test demonstration of a self-adaptive flutter suppression system for fighter aircraft (1990).

Approach: Low Observables Design, fabricate and test radar absorbing structures for their electromagnetic and structural performance. Acoustic detection work uses acoustic predictions for nonuniform media in conjunction with fly-over measurements for various weapon systems. Ballistic and Laser Vulnerability and Hardening Use ballistic ranges, laser ranges and laser simulators to evaluate the combined effects of structural loading and battle-damage. Repair Use new materials concepts, such as room temperature bonding of composites, to develop rapid structural repairs and to demonstrate them to Combat Logistics Support Squadrons in the operational commands. Operation on Short/Rough/Damaged Runwayse Use in-house computer programs, HAVE BOUNCE taxi tests and the AGILE test facility to compare theory and experiment for ground-induced loads on USAF combat aircraft. Active Flutter Suppression has used computer analysis and wind tunnel tests of aeroelastically scaled models; however, flight tests are planned for combat aircraft in the late 1980's.

Military Payoff: Survivable Structures R&D has the potential to provide (for current and future airframes): reductions in radar, infra-red acoustic and visual detectability; improved survivability to ballistic and laser threats with no appreciable weight increase; reduced vulnerability and increased sortie rates - we estimate that a 50% reduction in the time necessary to repair battle damaged structure could be achievable for 75% of repairs; assessment of and criteria for the operation of combat aircraft on rough, soft damaged and repaired airfields - based on tests using the AGILE facility, dramatic improvements in aircraft capability to operate on rough/soft/short airfields may be possible; and high speed, low altitude carriage of external stores - for fighter aircraft with external stores, investment in adaptive flutter suppression could double the speed for flutter onset for certain critical store combinations and allow safe carriage in high speed, low level flight.

Goal 2: Advanced Aeronautical Structural Concepts

Objective: New Alloys and Fabrication Process Demonstrate the ability of passive structural damping technology to substantially reduce noise and vibration in equipment bays of the B-1B (1989). Demonstrate high-temperature powder aluminum alloys to replace selected steel and titanium parts at reduced weight and cost (1988); full-scale demonstration of replacement of today's aluminum with lower density and/or higher strength aluminum alloys to improve strength, weight and corrosion-resistance (1991). Graphite/Epoxy Composites Evaluate the potential of very flexible, aeroelastically-tailored composite wings to provide high levels of maneuverability with active control surfaces (1989). Update the composites design guide, and develop methods to transfer the design techniques of integrally-damped metal structures to integrally-damped graphite epoxy structures (1990). High-Strain High-Temperature Composites Develop thermoplastic structures concepts to demonstrate reduced fabrication costs (1990). Demonstrate load-carrying structures for boost-glide vehicles (1990). Metal-Matrix Composites Develop reinforced superalloy structures for manned hypersonic vehicles and boost-glide missiles (1990); design and fabricate full-scale components for potential ATF applications and high temperature missiles (1989) and reentry vehicles and fan rotors (1991).

Approach: New Alloys and Fabrication Processes Employ major airframe manufacturers to build a few small components to illustrate typical or initial structural applications of advanced concepts. If successful, these are then expanded to major structural assemblies and subject to strength, fatigue and dynamic evaluations. These same procedures apply to Graphite Epoxy Composites. High Strain High Temperature Composites and Metal-Matrix Composites are both still at the stage of developing the materials processes and structural data bases from coupon tests. These applications will subsequently grow to components, structural assemblies and full-scale applications in secondary and primary structure.

Military Payoff: Advanced aeronautical structural concepts R&D has the potential to provide (for future airframes and retrofits to the current fleet) a 10-30% reduction in structural weight from baseline aluminum and titanium structures for the same mission and payload; a 25% reduction in fabrication costs via the elimination of many fasteners; a 20% increase in specific strength and specific stiffness; a 50% improvement in life cycle costs associated with durability; high-temperature aluminum for flight at temperatures up to 400 F; and the extension of sustained allowable temperatures of lightweight missile structures to 1100 F. Using graphite/epoxy composites on 50% of an advanced fighter structure could result in 20% weight reduction from today's baselines. High-temperature and high-strain organic composites are ready for advanced development which will allow their use at Mach numbers above 2.2, with even more weight reduction over graphite/epoxy.

Goal 3: Aircraft Structural Integrity

Objective: Conventional Mechanically Fastened Metals Improve the Air Force's capability to predict the long-term durability and economic life under the fatigue aspects of cracking, fuel leakage, and ligament breakage; develop an automated system to record the growth of cracks under cyclic loading during fatigue tests (1988). New Alloys and Fabrication Processes Double (at least) the fatigue-life of secondary structures on the A-7 and F-111 with laminated structures (1988). Assist AFLC to develop programs to continue to apply this technology to the existing fleet. Graphite/Epoxy Composites Develop experimental techniques to reproducibly introduce porosity into fatigue specimens and to evaluate its effects; compare the fatigue damage in coupons of many scaled sizes to determine if scaling effects are significant to predictions of airframe life (1988). Develop analytical techniques to design composite panels in the post-buckled region; develop a nonlinear finite-element program to predict the behavior after buckling; and verify the structural performance of panels that have been optimized for post-buckling response. Develop a design guide for applications of post-buckled structures for realistic aircraft environments of spectrum loading, combined loading, and unknown structural defects (1988). High Strain, High Temperature Composites Develop experimental design data on the impact damage-tolerance and humidity effects on the strength of new organic composites at room temperature (1988); high temperature effects to 350 F (1990). Metal Matrix Composites Perform a theoretical/experimental study of crack growth in fibre-reinforced metal-matrix structures, including overload effects. Follow with the development of a method to predict fatigue life (1988) and to predict the strength of multi-fastener joints (1990). Investigate the failure mechanisms in Kevlar-reinforced aluminum matrices (1990). Fuel Tanks Develop a method to determine the fuel sealing integrity of an integral fuel tank-during the airframe fatigue test. Determine if there is an unexpectedly strong coupling between fluid and structural vibrations at frequencies up to 30Hz; and complete the second cycle of the fuel-tank design handbook (1988).

Approach: R&D in Conventional Mechanically Fastened Metals will use the fracture lab and finite element methods, coupled with fracture mechanics analyses, to determine the growth of fatigue cracks from initial flaws in aluminum, titanium and steel structures. The effort also continually examines the USAF requirements for analyses of durability and damage-tolerance in an attempt to reduce inspection maintenance and other life cycle costs. For structural integrity of high-strain, high-temperature composites, New Metal Alloys and Fabrication Processes and Metal Matrix Composites use the same procedures, except that the test specimens are usually small elements of potentially useful new structural materials. Greater emphasis is usually placed on a description of the initial quality of those materials. The structural integrity of graphite/epoxy composites has reached the point where major structural components (fuselage panels, wing covers) and assemblies can be tested for strength and fatigue and results obtained for full-scale aircraft applications. R&D in the structural and fuel-sealing integrity of Fuel Tanks use the fuel tank test facility to simulate the effects of loading, high temperatures, low temperatures and vibration. Nearly all industry R&D ideas for new concepts for integral wing tanks and fuel tanks are evaluated.

Military Payoff: Aircraft structural integrity R&D can double (at least) the fatigue life of many secondary structures which have low lives in service; obtain additional weight savings from graphite/epoxy composites by allowing operation at increased load and strain levels; 50% reduction of structural inspection costs for advanced fighters by allowing (at least) doubled inspection intervals for laminated metallic and organic composite structures. Development of a fatigue and fracture data base for metal-matrix composites to achieve 20% recution in structural weight for fighters and 30% for manned, maneuverable reentry vehicles; and reduce by 50% the maintenance manhours per flight hour devoted to fuel tank sealing.

Goal 4: Spacecraft Structures

Objective: Maneuverable Reentry Vehicles Synchronize the Lab program with the NASP program. Develop additional concepts to represent a high-temperature structure, thermal protection systems and cryogenic tankage (1988). Evaluate structural concepts for strategic boost-glide vehicles (1988); demonstrate super-alloy welded structures (1989); develop methods to prevent aerothermoelastic instabilities (1990); validate carbon/carbon integral heatshield/structure (1992). Surveillance Satellites Develop design methods to optimize spacecraft structures in the presence of those active control systems and structural buckling; and develop structural concepts for efficient load-carrying zero-slop joints for deployable antennas (1988). Demonstrate full-scale application of the use of passive damping in equipment bays to improve the vibration environment and the reliability of satellite (RELSAT) electronic components; develop analysis and design methods to minimize thermal distortions and fatigue in large satellites; and perform a full-scale integration of passive and active controls (PACOSS) of the dynamic response of satellites in vibration environments, slewing maneuvers and pointing corrections (1989). Conduct shuttle-based flight tests for vibration control (VCOSS) by 1991. Weapon Satellites Develop active/passive methods to control the thermal distortion of high energy laser mirrors and their vibratory response to cooling fluid turbulence; develop and validate full-scale, intrinsically hardened structures for future maneuverable satellites (1990). Conduct fullscale demonstrations of active/passive control of structural, thermal and dynamic response in our structural and dynamic test facilities (1990).

Approach: R&D in Maneuverable Reentry Vehicles will employ major airframe builders to design and fabricate full-scale components of generic "hot" structures for Transatmospheric and Boost-Glide Vehicles. These components receive initial evaluation for strength, heat transfer, damage-tolerance, durability, stiffness and storage of cryogenic fuels at the contractor's facilities. Our structural test facility is being gradually re-equipped and upgraded to perform thermal and structural testing of full-scale components and complete vehicles. Loading, heating and instrumentation techniques will be developed - including the simulation of liquid hydrogen. Surveillance Satellites will design satellite structures which use new structural materials with passive and active controls for thermal loads and vibrations. In-house programs will examine the theoretical and experimental aspects of the active control of vibration response to slewing and pointing motions. A full-scale demonstration will be conducted in-house for the combined active/passive control of thermal loads, shape, and vibration for a structure which represents critical components of a slewing Weapon Satellite.

Military Payoff: R&D in spacecraft structures has the potential to reduce "jitter" by a factor of 20, improve brightness on target by a factor of 100 for space-based laser weapons and reduce structural weight fractions as low as 10% for manned, maneuverable transatmospheric vehicles. Carbon-carbon airframes can be developed for boost-glide, maneuverable reentry vehicles. For large surveillance satellites reduction of vibration levels to sub-micron levels will be possible by the late 1980's with the tripling of lifetimes to 15 years by integrated active and passive control of vibrations. Development of active and passive control of the structural shape of laser mirrors and the dynamic response of supporting structures will allow an increase of laser brightness on target by a factor of 100.

Goal 5: Technology Base

Objective: Ground-Induced Loads Develop and maintain the personnel, expertise, computational tools, data bases and facilities to allow the anticipation, prediction, measurement, interpretation and control of excessive dynamic ground loads on any current or future USAF or competitive aerospace vehicle (continuing). Flight Loads Extend today's linearized aerodynamic and structural methods to nonlinear problems associated with direct force control and with abrupt and/or large incidences and rates of motion. Exploit the exploding technology computational fluid dynamics to predict steady flight loads, unsteady loads, turbulence and buffet (1990). Thermal and Structural Analysis and Optimization Maintain the USAF center for NASTRAN; maintain the Aerospace Structures Information and Analysis Center (continuing). Develop a

USAF-wide structural data base and data base management system to service ASD, the ALC's, the laboratories and the operating commands (1988). Develop a computer program (including a vector version) for structural analysis and optimization of generalized aircraft and spacecraft structures to reduce structural design times from several months to one week (1989). Vibrations and Acoustics Develop methods to use the results of ground vibration tests (modal analyses) to create and/or modify analytical models of aircraft and spacecraft structures (1988). Maintain a consistent program of flight test vibration surveys and contact with other government/industry activities to be abreast of changing requirements and environments (continuing). Exploit the many possible uses of computational fluid dynamics to predict acoustics and larger-scale noise (1988). Remain abreast of emerging structural concepts and their vibracoustic environments to develop design criteria (continuing). Develop a comprehensive aeroacoustic reference work (1987). Determine if aeroacoustic sources are practical methods of controlling boundary layer separation and reattachment (1988). Develop active/passive methods to control the high frequency, random vibrations of extenally carried stores (1989). Complete the technology to apply integral damping to large metal and composite components (1990). Unsteady Aerodynamics and Aeroelasticity Exploit the payoff of highly flexible aeroelastically tailored wings in combination with active leading and trailing edge control surfaces to provide unprecedented maneuverability for new fighters (1987). Extend transonic unsteady aerodynamic prediction method XTRANS to complete vehicles, including boundary layers and vortex flows (1989). Explore extended capabilities of Euler codes. Structural Test Methods Develop strain sensors and loading techniques for structural testing to 2000°F (1988), 3000°F (1990), 4000°F (1992). Develop convective heating methods to simulate heat loads on high-speed airbreathing missiles (1989) and on sonic fatigue specimens for HVT. Dynamic Test Methods Rebuild the vibra-acoustic and sonic fatigue test capabilities, including high temperature considerations (1988). Applied Mathematics Develop methods of parameter identification to determine structural properties from static and dynamic tests (1988); continue to develop practical, efficient, state-of-the-art numerical analysis methods for the Wright-Patterson AFB computing community (continuing).

Approach: Ground-Induced Loads uses computer program TAXI for nonlinear time-history calculations, with data obtained from manufacturers or component tests as input. Flight-Loads attempts to develop methods to predict the flight loads on flexible structures at high angles of attack or at high rates of motion. The airframe industry will contribute to a USAF Workshop to examine the status of requirements for improvements in flight loads predictions. Structural Analysis and Optimization is primarily involved with the in-house development of structural optimization methods and in-house and industrial solution of system support problems, using mainframe computers and minicomputers. Vibrations and Acoustics uses modal analyses (ground vibration tests) and flight tests of fighter aircraft to develop design data for future aircraft and to provide modal data for analysis of loads flutter and dynamic response. Computational fluid dynamics, wind tunnel tests and water tunnel tests contribute to data on the acoustic environment in weapon bays. Unsteady Aerodynamics and Aeroelasticity attempts to solve the nonlinear finite-difference equations for transonic, unsteady, inviscid flows over clean wings. Follow-ons involve the geometric modeling of external stores, such as pylons, launchers, and nacelles until the complete vehicle can be analyzed. Structural Test Methods primarily is an in-house activity to maintain and upgrade the static test laboratory to develop test methods, solve system support problems, and prepare for future high-temperature testing needs.

Military Payoff: Technology base investments have the potential to allow assessment of an aircraft's rough field taxi capability at only 10% the cost of taxi tests and with better accuracy and control. The time for the preliminary design of airframe structures can also be reduced from several months to just a few days - including effects of loads, strength, stiffness and fatigue. The dynamic test capabilities, static and thermal test capabilities, and USAF-wide structural data base will allow the well-organized analysis and solution of fleet structural problems by the Laboratories, procurement agencies and Air Logistics Centers.

SECTION IV

VEHICLE EQUIPMENT/SUBSYSTEMS TECHNOLOGY

Investment Strategy and Relation to Forecast II and Lab Strategic Plan

Our strategy is to generate and assure the timely availability of demonstrated flight vehicle equipment and subsystem technology options and design and performance assessment methodologies responsive to Forecast II technology and system needs, and to the Laboratory investment strategy defined in the Management Overview. Strategy to support Forecast II System/Technologies is to: develop an embedded load carrying heat exchanger concept to cool vehicle skin in 2000°F - 5000°F range and convert it to useful onboard power; also, examine absorbtion of this heat by cryogenic fuel; develop versatile hypervelocity capsule crew escape concepts; develop tire technology to double current speed and load-carrying ability for horizontal takeoff of hypervelocity vehicles (500 m.p.h. at 150,000 lbs per tire); examine feasibility of powered wing-in-ground effect launch concepts for advanced transports and aerospace vehicles. Efforts under one group of specific goals address the needed increase in the the operational reliability and maintainability, and with it the reduction in life cycle cost, of major flight vehicle equipment and subsystems. Another group addresses the effective protection of major flight vehicle subsystems and equipment against nonnuclear combat threats and natural environment hazards. A third group addresses required increases in the operational capabilities of flight vehicles. The vehicle equipment/subsystem technical domain offers unique opportunities to significantly impact the operational capabilities and vulnerability reduction of flight vehicles, the survivability of aircrews, and the operational reliability of major flight vehicle subsystems. In addition, technology base expansions through the generation and feasibility demonstration of new concepts, design techniques, and performance assessment methodologies will form the basis for the selection of viable options for advanced flight vehicle design.

Key technical objectives and thrusts in the far term will emphasize flight vehicle and aircrew protection against the formidable chemical/biological and directed energy threats; development of Forecast II technology options for subsystem supportability, environmental control and environmental durability for the electronic flight vehicle; and long-life and high-efficiency cryogenic refrigeration capabilities. A conscious system view of flight vehicle equipment and subsystems will stress innovative approaches and effective subsystems integration to maximize utility to the total flight vehicle. Innovative approaches in the area of flight vehicle undercarriage will be pursued to provide economical and low penalty operational capabilities for a broad range of taxi/takeoff/landing surface characteristics and weather conditions. Crew compartment and emergency crew escape system technology goals will emphasize the expansion of the technology base for an integrated low profile/shirt sleeve environment cockpit and escape module combination to satisfy high-speed endoatmospheric escape requirements. Building on this foundation, comparable escape capabilities for Forecast II transatmospheric and space systems will be conceptually explored. Computer-aided integrated design, performance assessment and audit capabilities will become operational. The integration of equipment and subsystems into a federated digital control and diagnostics network will receive added emphasis. Special emphasis will be given to development of a low-life-cycle-cost landing gear and high-speed, highly loaded aircraft tires to enable horizontal takeoff and landing of Forecast II hypervelocity vehicles as will selected integration of test and simulation capabilities across disciplines starting with landing gear test equipment and a man-in-the-loop motion-based simulator.

In the advanced development area, a mission integrated transparency system will be emphasized to demonstrate the capability to incorporate protection against multiple threats and hazards with reasonable durability over its life cycle into the next generation of fighter aircraft transparencies while anticipating the changing mission roles over the aircraft life.

Pivotal surveillance capability technology in support of the Space Defense Initiative (funded by AFSTC) is addressed by emphasis on prototype cryogenic cooler hardware upscaling to meet refined load, temperature regime and life requirements. Develop thermal management (heat-pipe and thermal switches) technology and total spacecraft thermal control concept evaluation software; develop prototype hardware for spacecraft with unattended cryocooler life of 5-7 years by improving seals and magnetic bearings.

Support of the Department of Defense Live Fire Test Program is receiving priority access to the AFWAL Aircraft Survivability Research Facility in order to provide test-based assessment of the front-line aircraft hardness against contemporary ballistic threats.

Specific Goals and Technical Approaches

Goal 1: Integrated Environmentally Engineered Electronics

Objective: The acquisition of capabilities to design for and assess the reliability of electronics and avionics, from an environmental stress point of view, and to effectively detect flaws in printed circuit boards during the development and production cycles as well as predict hardware life as governed by growing latent defects. This includes the development of an experimentally validated and computerized methodology to assess and predict avionics operational reliability based on data and information available at preliminary and critical design reviews. An ultimate objective is the development of an accelerated environmental reliability test which will significantly reduce the prohibitively lengthy and expensive tests associated with modern high-reliability electronics.

Approach: A limited thermal analysis capability embodied in the Integrated Thermal Avionics Design (ITAD) computer program exists. The core of ITAD, its Data Base Management System (DBMS), will be upgraded to enhance the maintainability and user-friendliness of the program and accommodate the integration of individual stress analysis and life predictive routines during FY 88. The development and maintenance of computer software and work stations will be accomplished under a separate work effort. The vibration stress analysis code and the vibration/reliability relationship model will be combined into an Integrated Reliability Design Assessment (IRDA) capability to be used as a stand-alone assessment tool during the FY 89-91 time period to provide an expanded capability to design for and assess the reliability of electronics and avionics in the combined environments. Based on data and information available at preliminary and critical design reviews, IRDA will provide for the reliability assessment of individual printed circuit boards as well as of circuit boards integrated in line-replaceable-units (LRUs) within a given aircraft combined environment.

Experimentally evaluate techniques to detect (based on infrared and holographic principles) hot spots and flaws, respectively on microcircuit devices and printed circuit boards during environmental stress screening of developmental and production items; along with the development of a latent defects life prediction model or algorithm based on the phenomenological nature of electronic printed circuit board failures. The experimental validation of the latent defects life prediction model is programmed for completion in FY91.

Military Payoff: The attainment of validated capabilities to design for assess and predict the reliability of advanced electronics and avionics under environmental stresses will substantially contribute to the reduction of their operating and maintenance costs. Tools will be available to assess the projected reliability of avionics designs on the basis of data available at preliminary and critical design reviews. Thus, required design changes can be identified and incorporated into the design prior to commitment for production. The development of an accelerated environmental proof test will support the acquisition of avionics with a minimum specified failure-free life.

Goal 2: Internal Environment Control

Objective: Improve environmental control system concepts and long life, high effectiveness cryogenic coolers for aircraft, missile and spacecraft applications, together with the acquisition of analytical tools to design and assess the performance of thermal management systems and components. Develop a closed cycle environmental control system concept providing for the avoidance of internal aircraft contamination in a chemical/biological threat environment, develop cryogenic cooler options for aerospace vehicle applications, experimentally evaluate advanced environmental control system components, and enhance analytical tools for system and component designs.

A. Environmental Control Systems

Approach: Design, fabricate and subsequently evaluate a brassboard Integrated Closed Environmental Control System (ICECS) under a joint program to be accomplished in the FY 85-88 time period. The ICECS will be microprocessor controlled, incorporate a vapor cycle compressor, and will be optimized by providing a benign environment for crew and avionics while substantially reducing bleed and ram air penalties associated with current open-loop type environmental control systems. The development of a concept, integratable with a closed environmental control system, to avoid internal aircraft contamination in a chemical/biological (CB) threat environment is being pursued under a parallel program. The selection of a viable concept, resulting from a comprehensive evaluation of the effectiveness of potential techniques and devices to negate the ingestion of CB agents, as well as having the potential for cost-effective integration into the closed environmental control system was completed. Development of integratable contamination avoidance systems has been initiated with the actual integration into the brassboard ICECS for experimental evaluation programmed for FY 89. Emerging CB threat sensor technology will be closely monitored and evaluated for aircraft application under an in-house program. Integration of a CB threat sensor or sensor arrays for on-board installation will be initiated in FY 88.

Investigate approaches in FY87 for the development of actively cooled hypervelocity vehicle structures and cold walls in order to provide solutions to flight at temperatures which exceed the recommended limits of existing materials. Develop a methodology to trade the relative payoffs of various total thermal management concepts to permit identification of feasibility and benefits of using cryogenic fuel as a heat-sink or of converting aerothermal heat energy into power in various hypervelocity vehicle missions.

Military Payoff: The transition of microprocessor based closed environmental control system technology into military flight vehicles has the potential of reducing engine bleed-air use and reducing cooling ram-air drag by approximately 80%. For application to a tactical fighter aircraft this translates into fuel savings of approximately 7000 pounds (14% of the total payload) or a 5-10% penetration range increase. In addition, contamination of the crew compartment and avionics bays in a chemical/biological threat environment will be prevented with the integration of a threat-exclusion capability into the closed environmental control system. This has potential for increased flight vehicle sortie rate generation in an intense battlefield environment. Exploration of actively cooled structures will provide critical technology for Forecast II hypervelocity flight vehicles.

B. Cryogenic Cooling

Approach: Design, development, and laboratory evaluation of efficient, long life cryogenic refrigerators and associated electronic controls for use with infrared sensors planned for space based surveillance systems will continue. Long-term testing of, and improvements to, critical components of Vuilleumier (VM) cycle coolers will continue to be performed. To reduce power requirements and increase operational system capabilities, the development of a small, high-speed turbo-expander with high efficiency was completed and integrated into a turbomachinery refrigerator. By the end of FY 87, cryogenic cooler technology for a minimum of five-year operating life will have been demonstrated. The exploitation of magnetic refrigeration concepts has lead to the selection of a viable concept for subsequent development of a demonstration device. Solutions to the seal-wear and resulting internal contamination problem exhibited in small split-Stirling cycle cryogenic refrigerators are being addressed with the development of new contacting and clearance seal concepts. The resulting seal designs will be applied for the development of a highly reliable miniature missile cryogenic cooler, planned to be initiated in FY 88. With the completion of the development and laboratory evaluation of several critical components, the development of a lightweight helium liquefaction system for aerospace applications began in late FY 86 and will be completed in FY 89. Basic investigations to increase the performance capabilities of cryogenic regenerators in the low-temperature regime will continue to be pursued and culminate with the evaluation of a demonstration unit in FY 88.

Military Payoff: Ensure long duration, reliable operation of cryogenic cooling devices for space base surveillance system and missile applications. Improved mission effectiveness with lower life cycle costs will result for missile guidance systems where effective cryogenic cooling is essential.

Goal 3: Flight Vehicle Vulnerability Reduction

Objective: Development and experimentally verify advanced concepts and techniques, and the establishment of design criteria for the protection or hardening of flight and mission-critical subsystems and of the aircrew against nonnuclear combat threats, such as projectiles, warhead fragments, directed energy and against natural and induced environmental hazards.

A. Nonnuclear Combat

Approach: Characterization and simulation of foreign nonnuclear combat threats for flight vehicle fuel systems and structural components will be developed and their effectiveness experimentally verified. Feasibility and least-penalty approach for insuring suppression of ballistically ignited fuel fires and explosions due to larger high energy projectile impact will be determined during the FY 86-87 time period. The determination of the effects of combined threat and windblast on composite material panels and advanced structural components will be completed during FY 88 to provide an expanded data base for use in the design of combat damage tolerant structures. With the correlation of analytically derived residual stresses in ballistically impacted structural components with experimental data in FY 87, a predictive damage and residual strength assessment capability will become available. In FY 87, a theoretically derived computer-based capability for use in optimizing the design of damage tolerant structures will be validated and will contribute to the incorporation of vulnerability reduction features into aircraft design. Added emphasis will be placed in FY 87 on the development of a procedure for the design and attachment of armor to existing airframe structures wherein threat defeat capabilities, weight and cost-effectiveness, and ease of installation will be primary considerations. A high payoff vulnerability reduction concept identified in the In-house program provides significant fuel tank explosion overpressure suppression through a combination of fuel tank vapor space inerting and venting when suitable inertants are employed. All data and information resulting from these programs together with those to be acquired under the Tri-Service Joint Live Fire Program will be transferred to the Survivability Information Analysis Center (SURVIAC) for inclusion into the data base.

B. Electromagnetic Hazards and Threats

Approach: Simulated nuclear electromagnetic pulses (NEMP) established the similarities and anomalies between the lightning hazard and the NEMP threat for the development of common protective measures for onboard avionics and electronics systems. Improvements to be made to a fast risetime lightning simulator will result in a full capability portable device which will realistically simulate the atmospheric lightning hazard. All data and information acquired under previous efforts provide inputs into the Atmospheric Electricity Hazards Protection Advanced Development Program under which efficient system level electromagnetic hardening techniques and protection design criteria are being developed and demonstrated in a system concept. With the completion of the Advanced Development Program in FY 87 and its consolidation of design oriented lightning threat specifications, catalog of validated aircraft protection approaches, and hardening verification test equipment and procedures; the exploratory level lightning R&D will also be terminated (FY 87). A model of the coupling phenomena of the electromagnetic constituents of directed energy threats to electronics has been developed and enables projections of the threat to other power levels and wavelengths.

C. Transparent Crew Enclosures

Approach: Efforts are structured to satisfy the bird impact failure mode simulation, environmental durability, and optical vision aspects and requirements imposed upon transparency subsystems. Experimental verification of durability testing methods for coupons, and full-scale transparencies incorporating combined environment test approaches, will be continued. Analytical approaches for the assessment of the structural integrity of transparencies due to ballistic impact by birds and aerodynamic heating will be combined to provide a comprehensive capability in FY 87 for computer-aided-design and performance assessment of transparent crew enclosure systems. Planned extensions of the windshield aeroheating and thermal response analysis capability into the hypersonic flight regime, for Forecast II systems in FY 87, will culminate in FY 89 with a validated design tool to address the high-temperature technical issues of hypervelocity vehicle windows and transparencies. The feasibility of a concept to combine the transparent panel and its supporting and attachment structure in one forming process to achieve increased system durability and ease-of-maintenance will be exploited during FY 87. An advanced development program, proposed for initiation in FY 87, will address the integration of technologies and required advancements to provide a design concept for ATF type transparent crew enclosure systems with inherent durability, optical qualities, and protection features against natural environment hazards and combat threats during high-speed, low-altitude and all-weather penetration missions. An Engineering Development Program addresses the development of an alternate transparent crew enclosure system for the T-38 aircraft to provide increased birdstrike protection at 400 knots and the development and completion of in-service evaluation, in FY 86, of a one piece windshield system for the F-4 aircraft to increase birdstrike protection to 500 knots.

Military Payoff: Results of these efforts will significantly increase the safety of flight and reduce the vulnerability of flight vehicles, aircrews, and flight and mission critical avionics and electrical subsystems to threats encountered in the nonnuclear combat environment and to hazards posed by the natural environment. Validated design criteria will enable the development of combat damage tolerant fuel systems and structures, effective and balanced system level protection of avionics and electronics against the electromagnetic threat, and transparent crew enclosure systems hardened to successfully accomplish high speed in-weather combat penetration missions.

Goal 4: Emergency Crew Escape

Objective: Reduce aircrew fatalities and major injuries encountered during escape from aircraft during combat and non-combat in-flight emergencies through the exploitation of new technologies, and feasibility demonstration of advanced concepts for the development of more effective escape systems.

Approach: Define and subsequently develop and demonstrate an encapsulated crew escape system concept to provide for safe escape (in the high-speed flight regime) and protection during very high altitude escape as well as in a chemical/biological threat environment. The focus will be in providing a shirt sleeve environment and on the definition and integration of critical technologies such as reclined body positioning, visibility, module separation, module stability and control, and recovery and landing. A definition study to determine a cost-effective technique for the laboratory simulation and assessment of the dynamics of module separation and in-flight stability, as an alternative to rocket sled or in-flight testing will be continued. Initial concepts for effective emergency crew escape from Forecast II hypervelocity vehicles capable of flight in both the atmosphere and near-earth space will be delineated in studies that will be conducted during FY 87/88. A definition of issues and possible solutions pertaining to emergency escape and rescue of personnel from life-endangering situations capable of occurring onboard orbiting space stations will be completed by FY 89.

Military Payoff: The probability of fatalities and major injuries incurred during emergency crew escape will be significantly reduced and the performance envelope for safe escape will be expanded. The payoff involves the achievement of an optimum balance between aircrew safety and weapon system cost effectiveness. Furthermore, viable options for emergency crew escape from reusable Forecast II hypervelocity vehicles operating in endo/exo-atmospheric flight regimes can be provided through conscious extrapolations of encapsulized atmospheric crew escape technology.

Goal 5: Mechanical Subsystems

Objective: Advancement of conventional landing gear system technologies that will provide the capability for flight vehicle operation on rough, soft, short and narrow surfaces at reduced subsystem weight and life cycle cost and the development and demonstration of advanced conventional and alternate capabilities for horizontal takeoff and landing operations of Forecast II hypervelocity vehicles.

A. Conventional Landing Gear

Approach: Investigate the mechanism for tire damage and identify potential tire tread patterns or carcass constructions which attenuate the damage potential. Emphasize the development of low life-cycle-cost landing gear components. The landing gear is one of the most operation and maintenance cost-intensive aircraft subsystems with a relatively high weight fraction penalty. Application of composite materials and/or advanced manufacturing techniques to the more complex load carrying components of the landing gear for weight reduction and elimination of susceptibility to corrosion has been started. Technology development will be initiated in FY 87 to fill a critical deficiency of conventional tires to enable the horizontal takeoff and landing of Forecast II hypervelocity vehicles. The technology effort will be followed in FY 90 by development of a full-scale prototype tire with the requisite high-speed, high-load capabilities.

B. Alternate Mobility and Launch Concepts

Approach: In-house scale model investigations of horizontal-launch-type concepts which combine aircushion and wing-in-ground effects will be pursued to provide feasibility assessments and design data for application to the development of takeoff systems for Forecast II hypervelocity vehicles and intratheater airlift aircraft. In the outyears, studies of improvements to air cargo handling systems will investigate the potential of robotics and artificial intelligence to expedite the loading, unloading, and delivery of military equipment at austere sites. R&D work in aircushion based approaches to mobility will be terminated in FY 87 with the transition of the Air Cushion Equipment Transporter to the Air Force Logistics Command Aircraft Storage facility.

C. Robotic Concepts for Aircraft Turaround in Chemical Warfare

Approach: Apply robotics technology to aircraft ground servicing tasks in a chemical warfare base attack environment. The clear advantages of avoiding exposure, fatigue or drastically reduced productivity of maintenance personnel wearing encumbering protective clothing while sustaining aircraft sortie generation are potentially realizable through application of mobile robotics. Studies will identify by FY 88 tasks and specific approaches suitable for robotics applications to refueling, decontamination, weapons and stores loading and rapid cargo handling. The further development of selected high payoff concepts leading to feasbility demonstrations are planed to be undertaken begining in FY 88 and continuing into the outyears.

Military Payoff: Less dependence of aircraft on smooth, hard-surfaced runways; a decrease of the life-cycle cost of conventional landing gear systems; and a reduction of the rate of aircraft accidents and incidents during ground operations. High sortie-rate generation due to a substantial enhancement of capabilities for aircraft and equipment mobility and aircraft takeoff and landing on an austere airfield as well as post-attack environment. Horizontal-launch stage concepts contribute technology options for flexible basing of hypervelocity vehicles for operational missions in space and low-earth orbits, and offer increased payload fraction on station by allowing ultra-heavy undercarriages sized for launch conditions to be left behind. Robotics will contribute substantially to our ability to sustain sortie generation after an air base atack with chemical weapons.

Goal 6: Aircraft Battle Damage Repair (ABDR)

Objective: Provide proven techniques, procedures and design standards to assess, repair or defer battle damage to enable front line aircraft to be rapidly made available for combat missions. Generate and validate analytical methods and supporting data bases for the quantification of resources required to support aircraft battle damage repair. Bring the ABDR capability for the emerging aircraft to the same level as for current front line aircraft and improve the overall ABDR capability by 50%.

Approach: Employ existing and emerging technologies and data bases, to the extent possible, as a starting point. Vulnerability and rapid repair potentials will be addressed for all flight and mission critical subsystems and equipment. The results of preliminary investigations to determine the extent of damage to aircraft propulsion systems caused by the impact of projectiles and warhead fragments will be used in the ABDR technology advanced development program as data points. Under this program, existing ABDR capabilities for current front-line aircraft will be summarized and deficiencies identified. Advanced repair techniques, procedures, tools, and material will be developed and their adequacy and integrity demonstrated and evaluated in a simulated battlefield environment using full-scale aircraft as test beds. Design studies and training manuals will be generated for use by combat repair teams, and lessons learned together with concepts to reduce the damage criticality to subsystems and equipment in advanced aircraft designs will be published during FY 88. The development of an improved methodology for the quantification of resources necessary for rapid aircraft battle damage repair will provide, by the end of FY 88, capabilities for defining, quantifying, and predicting dynamic wartime ABDR parameters. A critical element of the rapid repair process is the assessment of the aircraft to determine the extent of damage, impact of damage on mission capability, repairability of the damage, and what resources are required to return the aircraft to mission capable status. Develop an operational system, which incorporates the capabilities for storing, rapidly retrieving and presenting the technical information required for aircraft battle damage assessment, for field use during the FY 87/88 time period. Transitioning of validated technology advancements for application to the existing fleet will occur on an incremental basis.

Military Payoff: This program will provide the techniques, procedures, and tools required to assess the extent of battle damage and perform the necessary rapid repairs of front-line aircraft in an intense battlefield environment. Substantial increases in combat sortie rate generation can be expected as a result of these technology advancements.

SECTION V

FLIGHT CONTROL TECHNOLOGY

Investment Strategy and Relation to Forecast II and Laboratory Strategic Plan

New Forecast II systems and technologies were defined during the past planning cycle. Over two dozen points of contact in the Flight Control Division have been designated to support Forecast II planning. By a conservative estimate over half of the FY88 resources shown in this plan already support Forecast II objectives. In addition to the direct support for several Forecast II Technologies, flight control is a critical part of the enabling technical infrastructure for other Forecast systems.

Flight Dynamics Laboratory Strategic Planning goals are the primary source of guidance for this technical area. These goals have structured plans for STOL and autonomous landing control and resulted in a major emphasis in this plan for hypersonic vehicle control systems and crew stations for trans-atmospheric flight. Laboratory interest in Reliability and Maintenance is reflected in the continuing emphasis on fault-tolerant control systems. The Laboratory's technology capability improvement objectives are strongly supported by the development of a new high-performance in-flight simulator (VISTA) and the expansion of the ground simulator capabilities. Crew Vehicle Integration, introduced as a new specific goal last year, continues to address a chronic problem area.

Control Technology Core is an enabling technical area for new system capabilities and for the improvement of existing system performance and reliability. New Control Technology applications will yield increases in range, speed, payload, accuracy, component and airframe durability. This area, always critical for flight safety, is also critical to mission survivability during navigation and attack at high speeds, from orbit down to within a wingspan of the treetops in all weather, day and night operations. The technology for today's reliability and fault tolerance is the foundation for self-diagnostics and self-repair that will characterize the ultra-reliable and low maintenance control system of the future. Fighter cockpit design is a chronic problem and technology to correct the problem is a major goal so that future cockpits can augment the pilot's inherent flexible, rapid decision-making capabilities to achieve a consistent combat advantage in both autonomous and cooperative operations.

Five program emphasis areas delineate this plan. Most technology integration programs are in the Trajectory and Attitude Control area. Dynamic Systems Control emphasizes the extension of control capabilities and the analysis of large multi-degree-of-freedom control systems. Fault-Tolerant Control Systems is a separate goal area because of the critical need to assure flight safety and reliability. Crew Vehicle Integration has been included to solve critical cockpit problems for current and future systems. And Control Technology Core is the area to develop essential general capabilities and the seedbed for new concepts.

Specific Goals and Technical Approach

Goal 1: Trajectory and Attitude Control

Objective: Design, develop and demonstrate (1) by 1991, integration of control and avionics systems for Tactical Air Superiority against the 1995 threat, (2) by 1992, hypervelocity vehicle control and crew system technologies necessary for autonomous manned and unmanned transatmospheric military missions in the year 2000 and (3) by 1990, the capability to land a tactical fighter in all-weather conditions on a 1500' X 50' runway. By 1995, develop and demonstrate trajectory/attitude control systems for improved and extended envelope performance range.

Approach: To be achieved: (1) by demonstrating on an F-15, control and avionics integration in the Integrated Control/Avionics for Air Superiority Program (ICAAS) using standard Ada software, (2) through the Boost Glide Vehicle Program, and Flight Control Hypervelocity Vehicle Technology Program and, (3) through the Autonomous Landing Program, the Passive Guidance System, and the STOL/Maneuvering Technology Demonstration Program. The transport and strategic aircraft flight management programs will emphasize performance optimization.

Military Payoff: The payoffs are (1) capability to attack and survive against multiple aircraft in an air combat engagement -- the ICAAS test vehicle will be a major demonstration of Ada software applications to flight critical F-15 digital flight control system, an integrated inertial reference system, and an integrated fire/flight control system (2) autonomous manned and unmanned hypervelocity military mission capability, and (3) capability to land on 1500' X 50' segments of damaged runways.

Goal 2: Dynamic Systems Control

Objective: Design develop and transition analytical methods, design tools, and experimental techniques that create the ability to effectively design control systems with highly integrated and interactive elements for future military aircraft and spacecraft by 1992.

Approach: (1) Develop robust multivariable systems design procedures and develop new theories and design methodologies for robust/adaptive control systems for future aircraft and spacecraft applications, (2) develop experimental/analytical stability and control data base, design criteria, such as flying qualities and maneuver metrics, systems design procedures/methods, hardware/software implementation requirements, and operational applications assessment for precise attitude and velocity vector control during large-amplitude maneuvers; (3) develop design methods necessary for dynamics control of highly integrated systems, e.g., aeroservoelastic design procedures and techniques for effectively integrating flight/propulsion control for maximum vehicle performance throughout operational envelope, (4) develop interactive, user-friendly systems design and analysis software based on machine intelligence design procedures. These programs must be module, transportable and integrated with an efficient data base management system.

Payoff: Utilization of new dynamic control concepts can yield estimated 20% reductions in aircraft structural weight, achieve 15% greater maneuver load factors at high supersonic speeds than currently possible, an estimated 20% increase in survivability in air combat and provide the pilot precise and crisp control of the vehicle at any angle of attack or sideslip throughout an expanded flight envelope.

Goal 3: Fault Tolerant Control Systems

Objective: Develop fault tolerant control sytems which provide uninterrupted and safe operation in controlling a flight vehicle in face of battle damage or natural internal failures. Provide control systems for flight and mission critical functions having less than one catastrophic failure per one billion hours, automatic reconfiguration from battle damage or natural failures, flexibility for growth and expansion, long-term unattended reliability with MTBF exceeding 300 operation hours, and a 95% probability of no maintenance between scheduled maintenance intervals of 2000 flight hours.

Approach: Using prior developments in reconfiguring microprocessor systems, laboratory demonstrate by 1988 an in-house integrated fault tolerant multiprocessor control system using the best available features of current architectures. Included is a study of array processors and bit-slice techniques, intelligent interfaces for each sensor and actuator for built-in monitoring, a fault tolerant bus having improved communications, and evaluation of all pertinent DOD standards with recommended improvements for compatibility with control applications. Using a previous flight test of an F-15 digital flight control system, expand the development base by including an Ada Based Integrated Control System (ABICS). This capability will enhance real-world useage of the DOD standard language for flight and mission critical systems applications by 1989. Develop a Self-Repairing Digital Flight Control System (using reconfigurable flight controls) to exploit control surface redundancy of advanced aircraft by utilizing multiple control surfaces to reconfigure after failures or damage. Flight evaluate on an unmanned low-cost research vehicle by 1987 and flight test on a tactical aircraft by 1989. Reduce life-cycle-cost and improve availability through artificial intelligent expert systems and automated maintenance diagnostics. Define control system processing and interface requirements for "Flight Control System 2000" by 1992. Establish an in-house Center of Excellence in artificial intelligence for its application to fault tolerant systems by 1991.

Military Payoff: Significant improvements are achievable in maintainability and survivability of future aerospace vehicles such as the Advanced Tactical Fighter (ATF); for example, an order of magnitude increase in mean-time-between-failures with graceful degradation on the presence of failure or battle damage. A significant increase in combat survivability will be gained without giving up peacetime safety. Maintenance manhours will be reduced by a factor of five, and life cycle costs reduced by one-third. Reductions in the level of hardware redundancy will result in line-replaceable units that will have a higher level of reliability than current hardware. A long term goal is to achieve a flight control system capable of enduring a short war without the need for normal maintenance or specialized "shop" support equipment. Fault Tolerant Control Systems will result in a dramatic increase in system availability.

Goal 4: Crew/Vehicle Integration

Objective: To exploit the decision-making and mission management capabilities of the crew member(s) in all phases of mission accomplishment by blending automatic and manual control functions to achieve total situation awareness, optimum crew workload, and mission effectiveness. Specifically: (1) develop cockpit design criteria for USAF weapon systems, near term efforts directed toward the ATF to long term Forecast II technology goals; (2) develop the crew system technologies necessary to provide situational awareness in tactical fighter aircraft; (3) develop crew system methodologies and computer-based tools for rapid design and evaluation of cockpit and crew system technologies; and (4) develop and apply artificial intelligence concepts in the cockpit for mission planning, pilot decision aiding and workload reduction.

Approach: Use a structured methodology that considers mission requirements, the operational environment and technology capabilities, and validate the design using mock-ups and high-fidelity simulation. Assess emerging crew system technologies (such as voice, flat panel displays, computer generated pictorial displays, helmet-mounted displays, artificial intelligence techniques) for performance benefits, affordability, and workload reduction (using projected mission requirements as the development criteria). Develop computer-aided techniques to allow more timely and objective design and evaluation of new crew systems. Apply this approach to the development of tactical aircraft and to spacecraft cockpits and crew stations.

Military Payoff: Application of emerging crew system technologies and artificial intelligence concepts in the cockpit will reduce crew workload and achieve capability for single-seat night, in-weather ground attack. Improved crew system design and evaluation methodologies could significantly reduce cockpit retrofit costs by eliminating deficiencies during the aircraft development phase.

Goal 5: Technology Core

Objective: Innovative technology core plans are divided into four major subgoals: (1) design and analysis methods to provide an adequate design data base, fundamental flying qualities criteria, and computer aided design tools. Major efforts in FY87-88 center on missile stability and control research, continuing the automated preliminary design DATCOM enhancement and data base for aircraft and missiles, and completing flying qualities research on the effects simultaneous degredations due to multiple failure modes and/or battle damage, (2) experimental and simulation facilities that stimulate creativity and to provide a check for analyses will be further developed. These facilities include the Engineering Flight Simulator Facility, the Crew Systems Integration Laboratory (CSIL), the Control System Development Laboratory, and the NT-33A and TIFS In-Flight Simulators; (3) Development of the Variable Stability In-Flight Simulator Test Aircraft (VISTA), (4) a continuing effort to create and develop devices and voice controls. Planned in-house facility improvements include computer-generated display systems for the LAMARS, symbolic processors for artificial intelligence research, and high-pressure hydraulics and high-voltage electrical supplies for the Actuation Laboratory. VISTA, a 2-place F-16D, will replace the 25-year old NT-33A in-flight simulator. Basic design tradeoff studies on VISTA have been underway in 6.2 since FY82. Advanced actuator developments will concentrate on high-pressure (over 3000 psi) low profile hydraulic actuators. New cockpit displays will evaluate display characteristics to develop display design criteria.

Approach: Major in-house simulation programs in progress or scheduled for FY 87-88 include supermaneuverability, STOL Fighter, and R&M Reconfigurable Flight Controls. Developments underway in Crew Systems Integration Laboratory include the Microcomputer Application of Graphics and Interactive Communication (MAGIC). The in-flight simulators have a full schedule of flight reserach experimentation for the AF, Navy, NASA, and foreign countries.

Military Payoff: Technology core is the seed bed for germinating new military capabilities. In addition, analytical and experimental capabilities for developing and evaluating flight control technical ideas are created to support the technical program in the Laboratory, ASD, and the Air Force.

SECTION VI

AEROMECHANICS TECHNOLOGY

Investment Strategy and Relation to Forecast II and Lab Strategic Plan

The cornerstone of the investment strategy for the Aeromechanics plan is the Laboratory's Strategic Plan and the results of Project FORECAST II. Specifically, our program has been influenced by the renewed interest in hypervelocity vehicles and technology areas depicted by PS-6, PS-14, PS-18, PS-23, PS-24, PS-28, and PT-24. The Forecast II hypervelocity vehicle area is being supported by Airframe/Propulsion Integration for hypersonic aircraft, weapon separation at hypersonic speeds up to M=25 and 220,000 feet altitude, performance optimization for advanced airbreathing rocket and hybrid propelled vehicles; and hypersonic aerothermodynamics. The STOL/STOVL, VTOL area is being supported by aeropropulsion, ground effects and transition efforts and by configuration technology investigations on the impact of low observables on four ASTOVL concepts. The space area is being supported by the MRRV/ERV flight technology demonstration program to validate critical disciplines for SDI. Other technology developments will support BGV, High-Speed Interceptors and the High Altitude, Long Endurance, Unmanned aircraft. The plan consciously addresses these technologies and vehicle concepts, as well as others noted in the Lab Strategic Plan such as STOVL and Advanced Technology Transport.

Our strategy is based on: a deliberate effort to establish joint programs and to pursue interorganization activities; pursuing a strong in-house research component in that 34% of the resources are committed to the development of effective research; and requirements expressed by the using or operational commands. Such joint programs and interorganizational relationships are the BMO program elements which have been established, as well as the FDL/APL Aeroconfigured Ramjet initiative. Our cooperative propulsion integration program with NASA and industry will continue as will the innovative weapons carriage activities - in close awareness of the complementary efforts being performed by the weapons community.

SAC and Space Command have been involved in the definition of future Military Aerospace Vehicles and the Aeromechanics plan, as a consequence, vigorously addresses the problems associated with advanced hypervelocity vehicles. These technologies also support the NASP in terms of technology base. To posture the technology at a sufficient level of confidence, effort will be directed toward an integrated hypervelocity Research Vehicle (HRV) which should accommodate the major technology needs of the full spectrum of hypervelocity vehicles. The calibration and initial testing in the SARL will be accomplished and augmentation of flow field diagnostics will be possible with the acquisition of supporting equipment such as the precision model support system.

Relative to advanced aircraft the direct ATF technology efforts will shift more toward the completion of generic technologies which focus on inlets and nozzles for low observables with increased emphasis on aeropropulsion components for missile applications. Particular attention will be directed toward technologies to understand the fundamental flow phenomenon which could establish the basis for performance. A subset of efforts which are enabling technologies or effective V/STOL and V/TOL configurations will be developed relative to fighters.

Specific Goals and Technical Approaches

Goal 1: Aerodynamic Design Methods

Objective: Develop automated interactive input data generation methods to reduce errors and to increase productivity when accomplishing complete aerodynamic analyses. Improve Transonic codes, particularly those which apply to canard-wing-body configurations, with attention directed at vortex flows, separated flows, and shock-boundary layer interactions. Develop a jet model for the prediction of the flow field surrounding a Short Take-Off and Landing (STOL) aircraft. Develop a computational store separation and trajectory method for evaluating the flow field in the proximity of a hypersonic aircraft. Develop rapid and accurate aerodynamic/aerothermodynamic analysis methods with emphasis on missiles and hypervelocity vehicles. Continue efforts to remove current limitations for analyzing the mutual flow interferences of complex geometries such as wing-stores, aircraft propulsion interaction with adjacent vehicle components and shock/vortex impingement on boost-glide and manned hypersonic vehicles.

Approach: Aerodynamic design methods are characterized by long-term continuous dedicated efforts required to bring each method into the weapons systems design cycle. Interim methods and solutions to significant portions of the overall design problem are continuously available, used and verified, or upgraded as necessary throughout long-term efforts. The design methods development is supported through the development of advanced graphics and automated geometry manipulation and computational grid software to accelerate the set-up time of the flight vehicle computer model. Methods are validated by comparing analytical results with experimental data.

Military Payoff: Numerical aerodynamic analysis is one of the most significant high-value technical capabilities for general use during the flight vehicle design cycle. Numerical analyses can enhance the designer's ability to achieve an optimum design, incorporate new technologies to maximum advantage, and provide a growing technical data base for innovative design concepts. Reductions in the time and labor required for analysis permits synchronizing the weapons system development cycles in all technical departments, improving design interfaces, and reducing technical risk. Experimental data are corrected for facility and scale effects and the implications of the data are expanded over the entire design space, resulting in fewer unknowns and lower development risks.

Goal 2: Computational Fluid Dynamics

Objective: Direct effort towards the research, development and validation of various computational fluid dynamics methods to be used in the simulation of flows about military aerospace vehicles. Algorithm advancements will be achieved through research in applying boundary conditions for zonal schemes and transonic flows; methods of improving efficiency of the algorithms and data management will be developed. Various methods which have been validated will be applied to numerically simulate the entire flow about hypervelocity flight vehicles. Experimental data required to validate these numerical methods will be obtained in such areas as vortex breakdown, jet in cross-stream, and nonequilibrium flows. Fundamental research of interdisciplinary nature wherein numerical simulations of fluid mechanics coupled with other physical disciplines will be conducted.

Approach: Advanced numerical algorithms will be developed to solve the Navier-Stokes and Euler equations on the Class VI vector and parallel processing computers. Fully implicit and mixed explicit/implicit algorithms will be investigated to improve efficiency. Three-dimensional graphics capabilities will be enhanced to aid the data management. Development of a grid and algorithm to numerically simulate hypersonic flow about the NASP related flow phenomena will be initiated. Experimental data on vertical flows about delta wings, dynamic stall of a pitching wing, strong jet injecting into oncoming stream, real gas phenomena due to high temperature, and non-equilibrium flows will be obtained to support numerical solutions. Fundamental research, numerically coupling the governing equations for fluid mechanics with those from the flight mechanics and reacting gases disciplines will be initiated in FY87.

Military Payoff: Computational aerodynamics will have an increasing impact upon system aerodynamic development as methods become available that have the power to provide timely inputs to the design process. Computational aerodynamics will be used for airframe-propulsion integration (requiring flow field data), aerothermodynamics (requiring detailed heat-transfer distributions), unsteady aerodynamics (requiring temporal interaction between viscous and inviscid flow fields), and for complete configuration aerodynamics. These analyses will complement experimental data and may eventually replace some of the wind tunnel tests that often pace system development. Reductions in design cycle time, improved synchronization of aggregate, and detailed aerodynamic data and elimination of practical simulation constraints will all contribute to reduced system development costs.

Goal 3: Aerodynamic Heating/Configuration Cooling Concepts

Objective: Accurately predict and manage the aerodynamic heating incident upon supersonic and hypersonic flight vehicles which is accomplished through the understanding of both the effects of configuration geometry as well as the influence of natural and induced flow chemistry on that geometry. While the primary emphasis is toward hypersonic applications where the rate of heating is highest, supersonic applications where more moderate heating occurs will also be considered.

Specific objectives involve an analytic understanding of the potential effects of non-equilibrium flows on non-catalytic surfaces in 1987, the engineering evaluation of the consequences of multiple pulse heating on HVT airframes in 1987. In 1988, an initial numerical capability will be established to predict the effects of non-equilibrium flows on practical three dimensional bodies. Also in 1988, improvements will be introduced into existing codes to increase their capabilities to predict leeside vortical flows. In 1990, a capability will be established to predict the effects of rarified hypervelocity flows over HVT sensors and windows, including the effects of localized active cooling; and in 1992, an efficient design capability will be available to predict flow field behavior in hypersonic low-density regime on full configurations.

Approach: Current and anticipated efforts will continue to rely on experimentation but the evolving problems of high energy flows and the reactions between such lows and vehicle surfaces will require an increasing reliance on the use of numerical simulation. Bolstered by capabilities to experimentally measure and numerically simulate complex three-dimensional flows which create significant interaction between the configurational surface and the flow field about it, develop highly effective and easily transportable design techniques. Internally, the approaches are aimed at generating data as accurately as possible. Externally, the approach is to employ that data to produce design techniques which can be incorporated with other goals to produce aerospace vehicles with exceptional capabilities.

Military Payoff: In the near term, studies of laser neutralization will give systems engineers an alternative to materials hardening for protection against laser threats. In the far term, this goal is directed at the efficient thermal design of aerospace craft such as BGV and HVT including NASP.

Goal 4: Airframe-Propulsion Integration

Objective: Develop design criteria and concept verification for advanced airframe-propulsion integration considering requirements for STOL, enhanced stealth, maneuvering agility, and efficient supersonic cruise. Develop the additional R&D information needed in the multi-function nozzle area to provide assurance of aerodynamic stability criteria and trim drag reductions with thrust vectoring for aero-control. Develop design criteria necessary to optimize inlet-airframe-nozzle design for hypersonic aircraft operating in the Mach 4 to 14 range.

Approach: Application of advanced airframe-propulsion integration concepts to tactical and strategic aircraft will be emphasized. Examples are shielded/stealthy inlets and nozzles, multi-purpose two-dimensional exhaust nozzles and agility enhancement (through energy/force management). Concentration on supermaneuverability goals for tactical aircraft will require further development of thrust vectoring/reversing and other forms of propulsive lift over a wide speed range assuring positive control to extreme vehicle attitudes. Implementation of computational fluid dynamics related to airframe-propulsion integration will facilitate concept screening for reduced drag, high installed thrust, in-flight maneuver capability, and aerodynamic stability and control augmentation. Development of hypersonic propulsion integration technology will be initiated by establishing innovative, synergistic airframe-propulsion integration concepts, performance evaluation methods and concept validation techniques.

Military Payoff: For air-breathing tactical and strategic aircraft, thrust vectoring can control the magnitude and direction of the velocity vector for enhanced air-to-air, air-to-surface accuracy through speed/maneuverability management. Increased missile capabilities (engagement and stand-off) can be achieved sufficient to protect the launch platform at reasonable weight and cost. Aircraft survivability can be enhanced by signatures reduced dramatically from current levels through low RCS inlets and low RCS vectoring nozzles. Survivability/effectiveness of interceptor reconnaissance, and strike aircraft can also be greatly enhanced by increased cruise Mach number operation up to Mach 6 or 8.

Goal 5: Aero Configuration Synthesis Technology

Objective: Formulate and evaluate advanced aircraft configurations which incorporate emerging aeromechanic and related technologies. Efforts will be conducted to fully assess the interface between radar cross section, infrared emissons and vehicle performance. Configurations with the optimum combination will be defined, analyzed, and tested to validate the signature and performance characteristics. Fighter configuration synthesis will include basic aerodynamic enhancement, as well as STOL and maneuvering improvements. VTOL configuration options need to be developed which are totally independent of concrete runways. Signature and drag reductions of conventional and advanced weapons will be investigated for all configurations. Large multi-purpose aircraft configurations will be developed that emphasize integrated aeromechanic technologies.

Approach: Synthesize advanced configurations by analyses, configuration trade-off parametrics, and experi-mental validation. Emphasis is required to blend emerging aeromechanic technologies into viable configurations that meet diverse performance requirements. Aerodesign integration studies reveal interrelationships between technical disciplines that affect configuration performance. Advanced aeromechanic and propulsion technology offer high potential for V/STOL Fighter configurations. Design efforts, wind tunnel tests, and signature tests are required for aerodynamic and performance validation.

Military Payoff: Technology advancements in wing design, weapon carriage, reduced observables, and vectoring thrust will permit the design of an efficient advanced fighter with excellent payload capability, rapid acceleration, maneuverability comparable to current fighters in the transonic regime, and superior capability in the supersonic regime. VTOL aircraft offer the potential for a high degree of basing versatility and utilize propulsivelift aerodynamics for increased maneuverability at subsonic and transonic speed.

Goal 6: Hypervelocity Vehicle Aeromechanics Technology

Objective: Develop integrated aeromechanics methodologies and technologies to evaluate hypervelocity vehicles related to possible future military aerospace systems such as the Boost Glide Vehicle (BGV) and the National Aerospace Plan (NASP), and to support the Ballistic Missile Organization (BMO) in technology areas required for their advanced reentry systems. Transitioning of some hypervelocity vehicle efforts into flight demonstration programs is expected to occur in the 1990's under such programs as the Military Research Reentry Vehicle (MRRV) and the Incremental Growth Vehicle (IGV) and the Aeroconfigured Advanced Ramjet Interated Technology Air Launched Missile. Specific concerns are: aerodynamic controllability of hypersonic systems at high altitudes, airframe/propulsion integration, real gas and catalytic wall effects in high energy flows, aerodynamic/structural heating solutions, and synergistic plane change maneuvering from orbit.

Approach: Hypervelocity Vehicle Technology (HVT) is a major AFWAL initiative encompassing the technologies and technology integration which will upgrade aerodynamics and performance methods, aero/structural heating schemes, increased understanding of real gas phenomena, aero/propulsion integrations for airbreathers and aero and reaction control systems trade-offs. For BMO, technological understanding of boundary-layer trips for decoys will be enhanced and code validation for various advanced reentry vehicles will be pursued as well as code upgrading. Extensive interdivision and interlaboratory efforts are continuing to produce the needed hypervelocity technology for aeromechanics/structures and aeromechanics/airbreathing propulsion integration. The FY87 new starts will explore the critical technology area of low density flows associated with vehicles required to perform extended flight at high altitudes. An effort to develop a more efficient and more accurate configuration design methods for high-speed aerodynamics will begin in FY87, using state-of-the art computer techniques to apply theories and extrapolate the experimental data base. A FY87 start will also investigate the flight performance implications of advanced airbreathing propulsion systems for hypersonic flight and identify trajectories where they are most efficient. Experimental programs will produce critical information for the data base needed to continue high-speed vehicle development. New experimental techniques will be developed that reduce test time in large production facilities by a factor of four. An optimum configuration will be developed for generic missions which will serve as a benchmark to evaluate specific configuration concepts.

Military Payoff: Reduce the cost and the design time of reusable highly maneuverable, survivable systems while improving their mission effectiveness through accurate and rapid computation of detailed aerodynamic, aerothermodynamic heating, and performance parameters early in the design effort. These systems will include Forecast II type vehicles requiring reusability and high cross range capability, aero-orbital transfer vehicles, single-stage-to-orbit vehicle (NASP type), and the BGV employing aeroconfigured concepts to increase agility, reduce observables, and provide substantial cross range.

Goal 7: Experimental Facilities and Instrumentation

Objective: Develop and improve aerodynamic test facilities, test and measurement techniques, flow field diagnostics, intrusive and nonintrusive instrumentation, and provide real-time, on-line data reduction for current and future test requirements; upgrade data acquisition instrumentation, develop interfaces to modern computer and improve techniques to enhance data reliability.

Approach: Ground test for design verification, with renewed emphasis on facility modernization, characterization and the synergism of complimentary techniques (i.e. Computational Fluid Dynamics with experimentation). The Subsonic Aerodynamic Research Laboratory (SARL) and the Vertical Water Tunnel will provide new laboratories in which to make concentrated studies of high-lift devices, ejector technology, vortex generation, dynamic stability, and ground-plane effects. Special emphasis will be placed on the development of nonintrusive diagnostic instrumentation and techniqnes to provide velocity data and physical insight to complement probe measurements. A program to develop an inexpensive, environmentally acceptable seeding material and technique will continue. Testing techniques and capability will be expanded to develop new levels of propulsion-airframe integration and dynamic stability testing. Test facility dependability will profit from increased emphasis on facility oriented preventive and equipment health maintenance programs.

Military Payoff: Programs to modernize and upgrade experimental test facilities and to develop a family of new nonintrusive instrumentation will positively impact design and analysis techniques, wind tunnel simulations, computational fluid dynamics, and configuration/component options which enhance mission performance and provide a high degree of confidence in the solutions to flight hardware difficulties during the FY88 - 92 time period. There is potential to make ground simulation testing highly efficient and selective, allowing for a rapid transition from test data to flight hardware.

Section VII

RESEARCH PROGRAMS

The Flight Dynamics Laboratory (FDL) considers the basic research program a key contributor to the vitality of its fully spectrum capability. Although basic research is considered to consist of the scientific search for new knowledge without a particular military application in mind, a dynamic research program can certainly provide the catalyst for innovative applied technology programs. In addition, Laboratory scientists involved in the basic research program provide a "technical core" that acquire awareness of current scientific activity outside the Laboratory, which when combined with their own in-house efforts, enables the FDL to be at the forefront in the search for scientific knowledge in FDL mission related technical areas. A viable basic research program is also a key element in attracting new and imaginative scientific and technical personnel.

Basic research programs in the Flight Dynamics Laboratory are carried out in those scientific disciplines and research areas where the discovery of new knowledge will be responsive to the program goals established by the Air Force Office of Scientific Research (AFOSR) and have the greatest potential for contributing to the FDL mission. FDL research task areas are:

(1) Computational aspects of fluid and structural mechanics including mathematical models of fluid flow, computational algorithm development and nonlinear dynamics.

(2) Behavior of metallic and composite components of airframe structures including durability/damage tolerance, acoustic excitation and thermal failure.

(3) Dynamics of aerospace vehicles including aerodynamics of flight control and analytical dynamics associated with large-amplitude maneuvers.

(4) Experimental aeromechanics research including boundary-layers in high-speed flow and separated flows.

(5) Structural dynamics and controls including design optimization of large space structures dynamics and controls.

(6) Computational aerodynamics including Navier-Stokes studies associated with interdisciplinary computational fluid dynamics, vortical flows, unsteady flows, and 3-D flows.

Details of specific investigations planned within these research task areas are described in the USAF Plan for Defense Research Sciences published annually by the AFOSR.

Section VIII

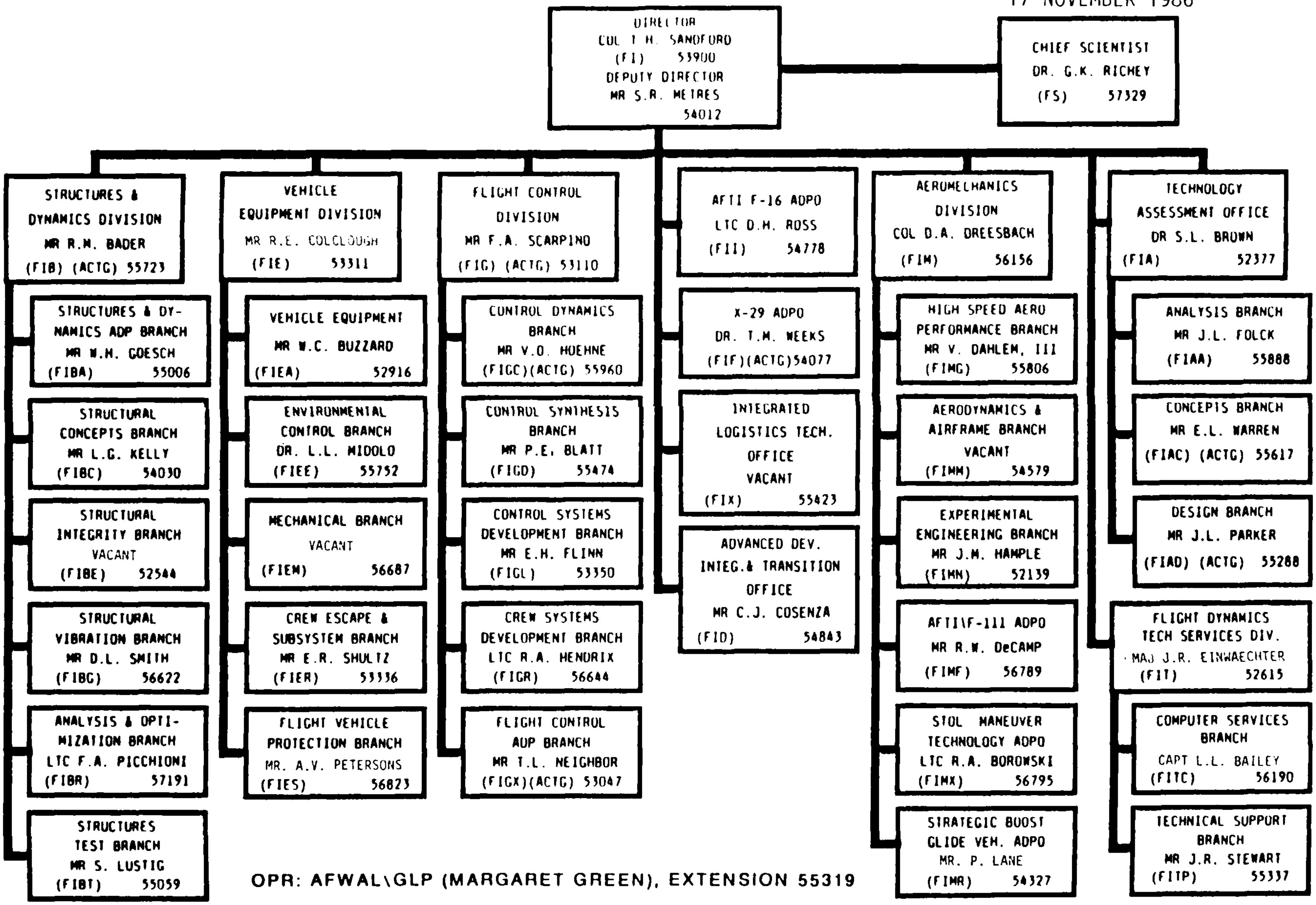
APPENDICES

Appendix I

Organization Chart

FLIGHT DYNAMICS LABORATORY

17 NOVEMBER 1986



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APPENDIX II

HOW TO USE THIS DOCUMENT

Unsolicitated proposals to conduct programs leading to the attainment of any of the objectives presented in this document may be submitted directly to an Air Force laboratory. However, before submitting a formal proposal, we encourage you to discuss your approach with the laboratory point of contact. See Appendix I Organization Chart. After your discussions or correspondence with the laboratory personnel, you will be better prepared to write your proposal.

As stated in the "AFSC Guide for Unsolicited Proposals" (copies of this informative guide on unsolicited proposals are available by writing to Air Force Systems Command/PMPR, Andrews Air Force Base, Washington DC 20334), elaborate brochures or presentations are definitely not desired. It is extremely important that your letter be prepared to encourage its reading to facilitate its understanding and to impart an appreciation of the ideas you desire to convey. Specifically your letter should include the following:

1. Name and address of your organization.

2. Type of Organization (Profit Nonprofit).

3. Concise title and abstract of the proposed research and the statement indicating that the submission is an unsolicitated proposal.

4. An outline and discussion of the purpose of the research, the method of attack upon the problem, and the nature of the expected results.

5 Name and research experience of the principle investigator.

6. A suggestion as to the proposed starting and completion dates.

7. An outline of the proposed budget including information on equipment, facility, and personnel requirements.

8. Names of any other Federal agencies receiving the proposal (this is extremely important).

9. Brief description of your facilities, particularly those which would be used in your proposed research effort.

10. Brief outline of your previous work and experience in the field.

11. If available, you should include a description brochure and a financial statement.

APPENDIX III

OTHER SOURCES OF INFORMATION

There are various sources for technical information produced by or for the United States Government and for notification concerning competitive procurement of research and development effort leading to such information:

SOURCE OF TECHNICAL INFORMATION

- Unlimited Documents

National Technical Information Service (NTIS)
US Department of Commerce
Springfield VA 22151

NTIS announces the availability of government technical reports through two periodical lists: "Government Report Announcements" (GRA) and "Government Reports Index" (GRI). The NTIS sells unclassified, unlimited reports to the general public.

- Limited Documents (Access requires a Government sponsor)

Defense Technical Information Center (DTIC)
Cameron Station
Alexandria VA 22314

DTIC publishes a periodical listing of technical reports in its collection. This "Technical Abstract Bulletin" TAB) is available to registered DTIC users.

SOURCE FOR INFORMATION CONCERNING GOVERNMENT R&D PROCUREMENT

Commerce Business Daily

A US Department of Commerce publication printed and mailed by the GPO Chicago IL.

For information and subscriptions contact:

Superintendent of Documents
Government Printing Office
Washington DC 20402

APPENDIX IV

FY 87/88 PLANNED NEW STARTS

FY 87

FIA

6.2

Survivable/Attack Fighter Technology Alternatives
Forecast II - Design and Analysis
Low Intensity Conflict Transport Technology Assessment
Advanced Weapon System Requirements
Advanced Design and Effectiveness Analysis

FIB

6.2

Develop Vax/Cray Version of FASTOP
Develop Structural Concepts for HVT Tankage
Develop Structural Concepts for HVT Thermal Protection
Develop Structural Concepts for Superalloy Curved Panels
Develop Structural Concepts for BGV
Noise, Sonic Fatigue for HVT
Shock/Vibration Isolation for External Stores
Develop Instrumentation for BGV
Develop Adaptive Thermal Controls for Struct. Test
Risk Analyses for Aging Structures
Thermomechanical Effects on MMC
Assess Flight Loads Problems in Combat Aircraft
Actively-Cooled Structures for HVT
Empirical Prediction Methods for Flight Loads

6.3

Demo Infra-Red Absorbing Structure
Demo Thermoplastic Structure (ML)
Develop Ceramic Nozzle
Demo RAS Supportable Structures
Develop 3D Carbon/Carbon Structure
Demo RAS for Fighters
Develop Ultralight Structures
Develop Hot/Cooled HVT
Boost Glide Vehicle Baseline Structure
Develop NDI Methods for Structures
Develop Supportable ATF Fuselage Structures
Demo Combined MMC/Integral/Damping for Satellite
Demo MMC Compressor Disk
Develop Integral Damping for Aft Fuselage Equipment Bays
Demo High Temp Aluminum Structures

FIE

6.2

Transparency Durability Validation
Transparency Hypersonic Thermal Analysis
Space Escape Definition
High Speed Highly Loaded Tire

6.3

Mission Integrated Transparency
Engine ABDR Utilization Criteria
ABDR Handbook
Portable Computer ABDR Assessment AID

FIG

6.2

Actuation for Hypervelocity Vehicles
Supermaneuverability Simulation
Advanced Fault Tolerant Flight Control
Stability and Control for Supermaneuverability
Robust Adaptive Control Application

FIM

6.2

Missile High Speed Flows
Low Density Flows for HVT
Performance Application to Adv Vehicles
Synthesis of Ultra Fighter Configuration
Hypersonic Cruise A/C Technology Integration

6.3

BGV Advanced Development Program

APPENDIX IV

(CONTINUED)

FY87

6.2

FIM

Configuration Synthesis for Long Endurance Vehicle
Advanced Zonal Analysis Method
Accel/Cruise Propulsion Installation Analysis
Axial Flow Compressor Instrumentation
High Normal to Axial Force Balance
High Mach, High Altitude Weapon Separation

FY88

6.2	6.3
FIA	
Space Systems Design and Analysis	
RCS Prediction Methods Development	
FIB	
Durability Prediction Method for High Temp OMC*	
Develop LH_2 Simulant for Thermostructural Testing	
Develop Concepts for "Smart Structures"	
FIE	
Hypervelocity Vehicle Thermal Management Concepts	ABDR Technology Development
Ballistic Threat Parameterization	
Threat/Armor Effectiveness Validation	
Aircraft Vulnerability Assessment Improvement	
Frameless Transparency Preliminary Design	
Emergency Crew Escape Capsule Critical Subsystem	
Dynamic Simulation Study	
Robotic Concept Development	
FIG	
Hypersonic Flight Control Simulation	
Operational Utility Assessment of Supermaneuverability	
VHSIC Applications to Fault-Tolerant Control System Designs	
Flight Critical Software Design Methods	
FIM	
TV/TR Jet Analysis Model	
Hypersonic Weapon Separation	
Geometry/Configuration Modification System	
Lift Augmentation Concept Evaluation	
Low Speed Characteristics of Hypersonic Vehicles	
Experimental Investigation of Nozzle/Aero Control	
Airframe/Nozzle Integration for M=8 to 14 A/C	
Hypervelocity Vehicle Pre-Design	
Adv Runway Independent Fighter	
Flow Diagnostic System for SARL	

* OMC = Organic Matrix Composites

U.S. GOVERNMENT PRINTING OFFICE 1987 - 748-002/40104

REPORT DOCUMENTATION PAGE

1a. REPORT SECURITY CLASSIFICATION	1b. RESTRICTIVE MARKINGS
2a. SECURITY CLASSIFICATION AUTHORITY	3. DISTRIBUTION/AVAILABILITY OF REPORT Approved for public release; distribution unlimited
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE	
4. PERFORMING ORGANIZATION REPORT NUMBER(S) AFWAL-TR-86-3000	5. MONITORING ORGANIZATION REPORT NUMBER(S)
6a. NAME OF PERFORMING ORGANIZATION Air Force Wright Aeronautical Laboratories, Flight Dynamics Laboratory 6b. OFFICE SYMBOL (If applicable) AFWAL/GLXRF	7a. NAME OF MONITORING ORGANIZATION
6c. ADDRESS (City, State and ZIP Code) Wright-Patterson AFB OH 45433	7b. ADDRESS (City, State and ZIP Code)
8a. NAME OF FUNDING/SPONSORING ORGANIZATION Air Force Wright Aeronautical Laboratories, Flight Dynamics Laboratory 8b. OFFICE SYMBOL (If applicable) AFWAL/GLXRF	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER
8c. ADDRESS (City, State and ZIP Code) Wright-Patterson AFB OH 45433	10. SOURCE OF FUNDING NOS.

PROGRAM ELEMENT NO.	PROJECT NO.	TASK NO.	WORK UNIT NO.
62201F	9991	35	LX

11. TITLE (Include Security Classification)
Air Force Technical Objective Document

12. PERSONAL AUTHOR(S)

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Yr., Mo., Day)	15. PAGE COUNT
Final	FROM Aug 85 TO July 86	July 86	56

16. SUPPLEMENTARY NOTATION

17. COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
FIELD	GROUP	SUB. GR.	Ablation and Models Aerodynamic Characteristics Aerodynamic Characteristics and Flow Fields

(Continued on Back)

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

The document presents an overview of the Laboratory Technology Planning Objectives of the Flight Dynamics Laboratory omitting specific funding and timing information of an "Official Use Only" nature. Technology planning objectives are described for Structures and Dynamics, Vehicle Equipment, Flight Control, Aeromechanics, and Technology Assessment.

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT UNCLASSIFIED/UNLIMITED ☒ SAME AS RPT. ☒ DTIC USERS ☐	21. ABSTRACT SECURITY CLASSIFICATION Unclassified
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18. Active Controls
Aerodynamic Configurations and Cost Effectiveness
Aerodynamic Control Surfaces
Aerodynamic Heating, Convection (Heat Transfer) & Environments
Aero-elastic Effects, Twist
Air Cushion Vehicles and Landing
Air Force and Cost Effectiveness
Air-to-Air
Air-to-Surface
Aircraft and Flutter
Airframe, Interactions and Propulsion Systems
Airframes, Military Aircraft, Survival (General) and Warfare
Ballistics, Impact and Test Facilities
Boost Glide Vehicles
Boundary Layer Computations
Canopies and Materials
Canopies and Penetration
Chambers, Environments and Test Facilities
Cockpit Automation
Cockpits, Display Systems for Military Aircraft
Cockpits, Multipurpose Controls, Voice Control
Composite Structures
Control and Environments
Control and Simulation
Control Systems and Digital Systems
Control Systems and Integrated Systems
Control Systems and Stabilization of Unstable Aircraft and Spacecraft
Cost Effectiveness and Trade-Off Analysis
Cost Reduction Technologies
Crews and Integrated Systems
Cryogenics and Refrigeration Systems
Diagnostic Equipment and Holography
Dynamics Flow and Holography
Dynamics and Structural Response
Elastic Properties, Materials, Plastic Properties and Response
Energy Management
External Stores
Failure (Mechanics) and Structures
Fatigue Life
Fire-Flight Control
Flight Control
-Robust Control System Architecture
-Artificial Intelligence/Fault Tolerant
-Terrain Following/Terrain Avoidance
-In-Flight Simulator
Flight Testing
Flow, Lasers and Media
Fluid Flow and Lasers
Flutter Suppression
Fly-by-Wire Control
Formulas (Mathematics) and Structures
Fracture (Mechanics)
Geometry and Nozzles
Heat and Sources
Landing Gear & Test Facilities
Lightning-Static Test Facility
Metals and Structures
Planning and Scientific Research
Structures and Vibration
Tires and Treads
Wind Tunnel Tests

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